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APPLIED MECHANICS REVIEWS

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MAGNETO-FLUID-DYNAMIC WAVES

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BASIC EQUATIONS

Magneto-fluid-dynamics (MFD) deals with the motion of electrically conducting fluids (either liquid or gaseous) interacting with electromagnetic fields. To describe MFD phenomena, one uses both electrodynamic and hydrodynamic variables.

The electromagnetic fields $\vec{E}$ and $\vec{B}$ and the electrical charge and current densities ρ_e and $\vec{j}$ are connected by Maxwell's equations:

$$\nabla \times \vec{E} + \frac{\partial \vec{B}}{\partial t} = 0 \qquad [1]$$

$$\nabla \times \vec{B} - \frac{1}{c^2}\frac{\partial E}{\partial t} = \mu \vec{j} \qquad [2]$$

$$\nabla \cdot \vec{B} = 0 \qquad [3]$$

$$\nabla \cdot \vec{E} = \rho_e/\epsilon \qquad [4]$$

In the M. K. S. system, the dielectric constant ϵ is 8.854×10^{-12} farad/m, and the permeability μ is 1.257×10^{-6} henry/m. Their product is $\epsilon\mu = 1/c^2$ where c is the light velocity. The displacement current term $\epsilon \frac{\partial \vec{E}}{\partial t}$ which is usually dropped in MFD must be retained if Eq. [2] is applied to waves of high frequency.

The basic fluid-dynamic variables are the mass density ρ, the velocity $\vec{V}$, and the pressure p of the fluid. In addition, the energy density $\mathcal{E}$ is supposed to be a known function of ρ and p. When friction forces and heat flow are omitted, the fluid-dynamic behavior will be governed by the conservation equations:

$$\frac{\partial \rho}{\partial t} + \nabla (\rho \vec{V}) = 0 \qquad [5]$$

$$\rho \frac{d\vec{V}}{dt} = -\nabla p + \vec{j} \times \vec{B} \qquad [6]$$

$$\rho\left(\frac{d\mathcal{E}}{dt} + p\,\frac{d}{dt}\,\frac{1}{\rho}\right) = \vec{j}\cdot(\vec{E} + \vec{V} \times \vec{B}) \qquad [7]$$

The current density is given by the expression

$$\vec{j} = \sum_s n_s e_s \vec{v}_s \qquad [8]$$

in which $\vec{v}_s$ is the average velocity of the particles of species s (electrons, ions) and n_s and e_s are their number per unit volume and their charge. To a high degree of accuracy, the electric charge density $\rho_e = \Sigma\, n_s e_s$ is zero except near surfaces. The velocities obey the equations of motion

$$m_s \frac{d\vec{v}_s}{dt} = e_s(\vec{E} + \vec{v}_s \times \vec{B}) - \frac{1}{n_s}\nabla p_s + \frac{1}{n_s}\sum \alpha_{rs}(\vec{v}_r - \vec{v}_s) \qquad [9]$$

By combining these equations and replacing the $\vec{v}_s$ by $\vec{V}$ and $\vec{j}$, one can derive the momentum Eq. [6] and a generalized version of Ohm's law,

$$\vec{E} + \vec{V} \times \vec{B} = \frac{\vec{j}}{\sigma} + \frac{m_e}{n_e e^2}\frac{\partial \vec{j}}{\partial t} + \frac{1}{n_e e}(\vec{j} \times \vec{B} - \nabla p_e) \qquad [10]$$

In addition to the familiar resistive term with the electrical conductivity in the denominator, one recognizes on the right-hand side terms which can be ascribed to inertia, the Hall Effect, and diffusion.

In discussing MFD waves, we shall find conditions where interesting results are obtained if these three terms are not included. The still simpler equation

$$\vec{E} + \vec{V} \times \vec{B} = 0 \qquad [10a]$$

for infinite conductivity σ is also frequently used in place of Ohm's law.

In cases where the Hall effect plays an important role, it is advisable to make direct use of the Eqs. [9] rather than of the Eqs. [6] and [10]. In addition to simplifying the algebra, this separates more clearly some effects which are associated with the presence of the individual species.

Under conditions of low density and high temperature where the mean free path of electrons and ions is large, one introduces velocity distribution functions $f_s(\vec{r}, \vec{v}, t)$ from which the particle density and the average velocity are calculated as $n_s = \int f_s d^3\vec{v}$ and $\vec{v}_s = \frac{1}{n_s}\int \vec{v} f_s d^3\vec{v}$. The functions f_s are solutions of the Boltzmann equation

$$\frac{\partial f_s}{\partial t} + \vec{v}\cdot\nabla f_s + \frac{e_s}{m_s}(\vec{E} + \vec{v} \times \vec{B})\frac{\partial f_s}{\partial v} = \left(\frac{df_s}{dt}\right)_{\text{coll}} \qquad [11]$$

If collisions are so infrequent that one can set the right-hand zero, Eq. [11] is known as the Vlasov equation.

LINEARIZATION

The MFD equations are nonlinear but for small amplitude motion they can be linearized. In a linear theory, a sum of solutions of a set of equations is again a solution. One can thus solve a general problem by expanding in terms of eigenfunctions. In an infinite medium, such eigenfunctions are simple waves where the dependent variables are of the form

$$f = f_0 + f_1 \exp i\,(\omega t - \vec{k}\cdot\vec{r})$$

Substituting these expressions into the basic equations, one can separately balance zero- and first-order terms and ignore second- and higher-order terms, thus obtaining a system of linear homogeneous equations between the f_1's. The system possesses a nonzero solution if the determinant is zero. In this manner, one is led to *dispersion relations* between the propagation vector $\vec{k}$ and the frequency ω. In ordinary fluid dynamics, this procedure leads to a theoretical description of sound waves. In MFD, one finds a larger variety of waves depending on the relative direction of $\vec{k}$, the particle motion, and the fields.

In general, dispersion relations extend to complex values of $\vec{k}$ and ω. If one treats an initial-value problem, one Fourier expands the space dependence of the variables. This implies that $\vec{k}$ is real. The frequency ω, however, may be complex and, depending on the sign of the imaginary part of ω, such a wave either decays or grows. If one treats a propagation problem, one expands the time dependence, ω remains real, and $\vec{k}$ may be complex. By inspecting the dispersion relation, one can distinguish between amplifying and evanescent waves.

In some important dispersion relations, k^2 is a real function for real values of ω, but changes sign in passing either through a resonance frequency where $k = \infty$ or through a cut-off frequency where $k = 0$. In the frequency intervals where $k^2 < 0$, k is imaginary, and a propagating mode does not exist.

NO D-C MAGNETIC FIELD

When there is no zero order or d-c component of the magnetic field, the term $\vec{j}\times\vec{B}$ which occurs in Eqs. [6] and [10] is of second order and is therefore omitted when these equations are linearized. Under conditions where the diffusion term in Ohm's law is insignificant, the electrodynamic and the fluid-dynamic equations are uncoupled and have independent solutions. In addition to ordinary sound waves, one finds two types of electromagnetic waves. In the one type, the oscillations of the electric field and of the current are longitudinal, i.e. parallel to the propagation vector $\vec{k}$. There is no magnetic field associated with this type of wave. Its dispersion relation degenerates into a relation fixing ω independently of k. Such waves have a group velocity zero and therefore do not propagate any energy. The frequency is given by

$$\omega\,(\omega - i\,\omega_c) = \omega_p^2 \qquad [12]$$

where $\omega_p = \sqrt{\dfrac{ne^2}{m\epsilon}}$ and $\omega_c = \dfrac{ne^2}{m\sigma}$ are the so-called plasma frequency and the collision frequency of the electrons. The roots of this equation are complex and lie above the real axis, which means that the waves are damped.

The second type is essentially an ordinary electromagnetic wave with $\vec{E}_1$ and $\vec{B}_1$ at right angles to each other and to $\vec{k}$. Its dispersion relation is

$$(\omega^2 - k^2c^2)\,(\omega - i\,\omega_c) = \omega_p^2\,\omega \qquad [13]$$

In a sufficiently well ionized plasma, such as the ionosphere or low density air which has been heated by a strong shock, ω_c is quite small compared to ω_p. If one neglects ω_c, Eq. [13] reduces to the simpler form

$$k^2c^2 = \omega^2 - \omega_p^2 \qquad [14]$$

which has the cut-off frequency $\omega = \omega_p$. Below ω_p no wave propagation is possible.

ALFVÉN WAVES

In the presence of a d-c magnetic field $\vec{B}_0$ which will be assumed to be constant throughout the entire space, one encounters a very large variety of dispersion relations whose character depends on the magnitude of ω relative to ω_p, ω_c, and the various gyrofrequencies $\omega_e = \dfrac{e\,B_0}{m}$ and $\omega_i = \dfrac{e_i\,B_0}{m_i}$ of electrons and of ions of the species i. In what follows, we shall assume the fluid to be a sufficiently good conductor so that we can neglect ω_c. When ω is small compared to all the ω_i one can follow Alfvén and use Ohm's law in its simplest form $\vec{E} + \vec{V}\times\vec{B} = 0$. Eliminating all but $\vec{v}_1$ the linearized magneto-fluid-dynamic equations reduce to

$$\omega^2\vec{v}_1 - v_s^2\,(\vec{k}\cdot\vec{v}_1)\,\vec{k} = \frac{1}{\rho_0\mu}\,[(\vec{k}\times\vec{v}_1)\cdot\vec{B}_0\,(\vec{k}\times\vec{B}_0) - k^2\,(\vec{B}_0\,\vec{v}_1)\,\vec{B}_0 + k^2\,B_0^2\,\vec{v}_1] \qquad [15]$$

where $v_s = \sqrt{\gamma p_0/\rho_0}$ is the ordinary sound speed in the fluid. This three-component vector equation reduces to one equation for the component of $\vec{v}_1$ in the direction of $\vec{k}\times\vec{B}_0$ and a pair of coupled equations for the other two components. For the former, $\vec{v}_1$ is perpendicular to $\vec{k}$ so that there is no compression of the fluid. This is therefore a pure shear wave and its dispersion relation is

$$(\omega/k)^2 = v_A^2\cos^2\theta \qquad [16]$$

where θ is the angle between $\vec{k}$ and $\vec{B}_0$, and $v_A = B_0/\sqrt{\rho_0\,\mu}$ is the so-called Alfvén velocity. In the other two modes, the motion of the fluid takes place in the plane of the two vectors $\vec{k}$ and $\vec{B}_0$. For angles θ between 0 and $\pi/2$ each mode is a mixture of compression and shear waves. The phase velocities $v_p = \omega/k$ of these modes are found from the dispersion relation

$$(\omega/k)^2 = \tfrac{1}{2}\,[v_A^2 + v_s^2 \pm \sqrt{(v_A^2 + v_s^2)^2 - 4\,v_A^2\,v_s^2\cos^2\theta}] \qquad [17]$$

ANISOTROPIC WAVE PROPAGATION

One can visualize the manner of propagation of waves in some medium with the aid of a surface which is formed by the vectors whose directions are those of the wave normals and whose lengths are the phase velocities in these directions. For ordinary light in an isotropic medium, this *wave-normal surface* is a sphere. In an anisotropic medium, such as a crystal or a plasma in a magnetic field, the surface is not spherical. The phase velocities of the three characteristic MFD wave modes, given by Eqs. [16] and [17], lie on the three surfaces of revolution generated by the polar diagrams of Fig. 1, which has been drawn for the case that $v_A > v_s$. The outer surface belonging to the *fast mode* is *mildly anisotropic* and looks like wave normal surfaces in crystal optics. The surfaces of the *intermediate* and of the *slow* wave are *highly anisotropic*, differing qualitatively from the former surface in that they pass through the origin.

The method of geometrical optics which considers light (or other types of waves) as traveling along *rays* gives a considerably simpler picture of its propagation than wave optics and is adequate except for dealing with diffraction and phenomena near boundaries. Geometrical optics can be deduced from wave optics by considering groups of waves whose wave vectors $\vec{k}$ lie close together. By interference, the amplitude of a group like this can be made to vanish everywhere except in a small region of space, forming what one calls a *wave packet*. The velocity of a wave packet has the components

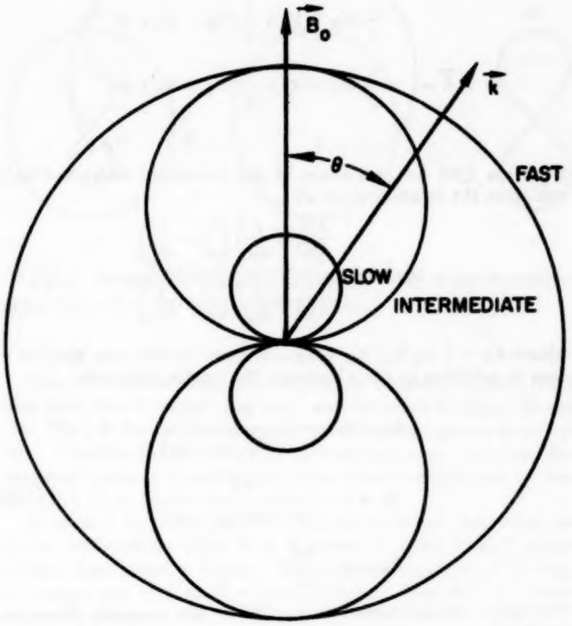

Fig. 1. Wave-Normal Surfaces for Alfvén Waves.

$v_{ge} = \dfrac{\partial \omega}{\partial k_e}$ where the derivative is taken at the central $\vec{k}$ of the group. It is important to realize that there is a difference between this *group velocity* $\vec{v}_g$ and the *phase velocity* $\vec{v}_p = \dfrac{\omega}{k^2}\vec{k}$. The line along which the wave packet moves defines the ray. Its direction generally differs from the corresponding wave-normal except where the wave is tangent to the wave-normal surface. The latter condition holds in every direction for the spherical wave-normal surface of an isotropic medium.

Given a wave-normal surface, one can find the direction of the ray associated with a wave-normal by the following geometrical construction. Through each point of the wave-normal surface, one constructs the plane associated with that normal. The envelope of these planes forms a new surface and the point of tangency between any one plane and the envelope lies in the direction of the ray associated with that plane. The points in this *ray surface* have a distance $v_p/\cos\alpha$ from the center, where α is the angle between ray and wave normal.

With the magnetic field as an axis of symmetry, the ray lies in the same plane as the magnetic field and the wave normal. The angle α between the wave normal and the ray (counted positive away from the magnetic field) can be calculated from the equation $\tan\alpha = \dfrac{1}{v_p}\dfrac{\partial v_p}{\partial \theta}$. The magnitude of the group velocity is $v_g = \dfrac{\partial \omega}{\partial k} \Big/ \cos\alpha$ so that its component parallel to k turns out to be $\dfrac{\partial \omega}{\partial k}$.

In Fig. 2 we present the ray surfaces corresponding to the wave-normal surfaces of Fig. 1. The ray surfaces of weakly and of strongly anisotropic modes have an entirely different character. The former enclose the origin so that there are rays going in all directions. The latter are restricted to small regions near the axis so that there are no rays inclined by more than a critical angle relative to the magnetic field. For the intermediate wave, as a matter of fact, the ray surface contracts into the points where the axis intersects the wave-normal surface. Because of this singularity there exist disturbances traveling along field lines without radial attenuation. Within the critical angle existing for the slow waves there are two group velocities for every ray direction. H. Grad has pointed out that, because of this, an initially smooth disturbance will develop singularities (Ref. 1).

LARGER FREQUENCIES

The above dispersion relations are valid only at low frequencies. As the frequencies become comparable in magnitude to the lowest ion gyrofrequency ω_i one must calculate the current with the aid of Eqs. [8] and [9]. This has the effect of separating the wave-normal surfaces of the fast and the intermediate modes which previously, as shown in Fig. 1, were in contact for $\theta = 0$, i.e., for waves traveling parallel to the magnetic field. The split into two modes arises together with a circular polarization. In the fast mode, the electric field rotates in right-hand fashion and in the slow mode, in left-hand fashion around the direction of $\vec{B}_0$. We designate these two modes as R and L waves and emphasize that this refers to the rotation around $\vec{B}_0$ and not of $\vec{k}$. For a plasma containing one species of ion, the dispersion relation for these modes is:

$$(kc/\omega)^2 = 1 - \frac{\omega_p^2}{(\omega \pm \omega_i)(\omega \mp \omega_e)} \qquad [18]$$

with the top and bottom signs applying to R and L waves respectively. Making use of the relation

$$\frac{\omega_p^2}{\omega_e \omega_i} = \frac{n\, m_i}{\epsilon B_0^2} = (c/v_A)^2,$$

the phase velocity of the two modes can be expressed in the form

$$\frac{\omega}{k} = v_A \sqrt{1 \pm \frac{\omega}{\omega_i}}$$

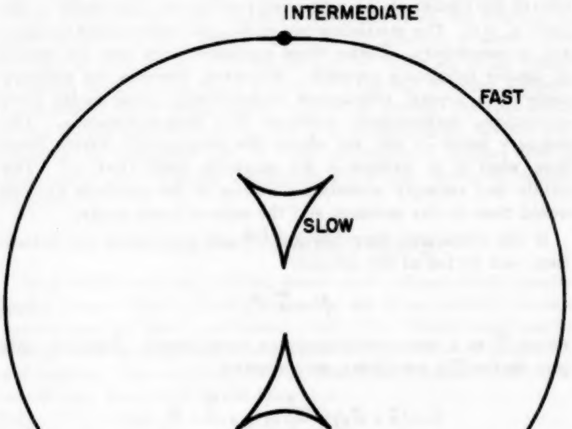

Fig. 2. Ray Surfaces for Alfvén Waves. Note degeneration into points for the intermediate wave.

which is valid for frequencies which are small compared to the gyrofrequency of the electron. For zero frequency, the two modes coincide with the one for Alfvén waves obtained with the simple form of Ohm's law.

Two opposite circularly polarized waves can be combined to form one linearly polarized wave. Because of the difference between the two phase velocities, the plane of polarization turns along the path of the wave. Just as for ordinary light this rotation is known as the Faraday effect.

At the ion gyrofrequency, L waves have a resonance and above that frequency only R waves are transmitted. Their dispersion gives rise to an interesting phenomenon known as whistlers (Ref. 2). In a large part of the frequency interval between ω_i and ω_e, the wave-normal surface containing the R waves has a strongly anisotropic character like the surface for slow Alfvén waves. Rays are therefore formed preferentially along the magnetic axis. Such waves follow the magnetic field lines even when these are curved as in the earth magnetic field. An electromagnetic signal, which may for example be due to lightning, consists of many frequencies. The dispersion causes the lower frequencies in such a signal to travel more slowly and to arrive later than the higher ones. In the earth magnetic field, ω_i is in the low acoustic range and if one feeds such signals, which are picked up by an antenna, through an audio amplifier to a speaker they appear as whistling sounds sliding from high to low frequencies. From an analysis of whistler observations, one can obtain important information on the ion density in the atmosphere.

At the much higher electron gyrofrequency ω_e the R waves have a resonance. Beyond ω_e there is a frequency range where k is imaginary for both R and L waves and neither of these waves are transmitted. At sufficiently high frequencies, the dispersion relations of both R and L waves have again real solutions k. In that range, we can identify these modes with ordinary electromagnetic signals traveling with nearly the velocity of light.

For waves traveling at an angle θ relative to the magnetic field, the analysis becomes more involved. We will sketch the results for the case where the ordinary sound velocity is much smaller than the Alfvén velocity so that one can set it zero. One also calls this the zero temperature approximation. With decreasing sound velocity the slow wave-normal surface shrinks toward the center of the polar diagram and it disappears in the limit $v_s = 0$. The remaining two modes are often called *ordinary* and *extraordinary*. These terms are taken over from the optics of doubly refracting crystals. However, whereas the ordinary mode in a crystal propagates isotropically, both modes have anisotropic wave-normal surfaces in a magneto-plasma. The ordinary mode is the one where the propagation differs least from what it is without a d-c magnetic field (Ref. 3). The mildly and strongly anisotropic modes of the previous section would thus be the ordinary and the extraordinary mode.

If one linearizes Eqs. [8] and [9] and eliminates the velocities, one is led to the relation

$$\vec{j}_1 = \overleftrightarrow{\sigma}\, \vec{E}_1 \qquad [19]$$

where $\overleftrightarrow{\sigma}$ is a tensor with complex components. Entering this into Maxwell's equations, one obtains

$$\vec{k} \times (\vec{k} \times \vec{E}_1) + \frac{\omega^2}{c^2}\left(1 + i\frac{\overleftrightarrow{\sigma}}{\epsilon\omega}\right) \vec{E}_1 = 0 \qquad [20]$$

For the purpose of writing the dispersion relations, it is convenient to introduce

$$\overleftrightarrow{K} = 1 + i\frac{\overleftrightarrow{\sigma}}{\epsilon\omega}$$

In a coordinate system where the z-axis is parallel to $\vec{B}_0$ the tensor $\overleftrightarrow{K}$ has the form

$$\overleftrightarrow{K} = \begin{pmatrix} \frac{1}{2}(K_R + K_L) & \frac{i}{2}(K_R - K_L) & 0 \\ -\frac{i}{2}(K_R - K_L) & \frac{1}{2}(K_R + K_L) & 0 \\ 0 & 0 & K_p \end{pmatrix}$$

Equation [20] has solutions if the *refractive index* $n = kc/\omega$ satisfies the relation (Ref. 4)

$$\tan^2\theta = -\frac{\left(\frac{1}{n^2} - \frac{1}{K_R}\right)\left(\frac{1}{n^2} - \frac{1}{K_L}\right)}{\left(\frac{1}{n^2} - \frac{1}{K_p}\right)\left(\frac{1}{n^2} - \frac{1}{K_T}\right)} \qquad [21]$$

where $K_T = 2\, K_R K_L / K_R + K_L$. If there is only one species of ions in addition to the electrons, the coefficients are:

$$K_R = 1 - \frac{\omega_p^2}{(\omega + \omega_i)(\omega - \omega_e)}$$

$$K_L = 1 - \frac{\omega_p^2}{(\omega - \omega_i)(\omega + \omega_e)} \qquad [22]$$

$$K_p = 1 - \frac{\omega_p^2}{\omega^2}$$

For waves whose normal is parallel to the magnetic field, i.e. for $\theta = 0$, one of the two factors in the numerator must be zero and we recognize the dispersion relations of Eq. [18] for R and L type modes.

If the wave normal is perpendicular to the magnetic field, one has $\tan\theta = \infty$. By setting the factors of the denominator equal to zero, one obtains two other dispersion relations. The mode for which $n^2 = K_p$ is distinguished by having electric field and current density oscillations parallel to B_0. In this mode, there is therefore no interaction between the current and the field B_0, and no effect of that field on the index of refraction. This can be seen from the expression for K_p given by Eq. [22]. That expression also shows that there is no transmission in this mode for $\omega < \omega_p$ since $K_p < 0$. Above ω_p where K_p is positive, it is less than one, so that the phase velocity of these waves is larger than the velocity of light. The other mode has an elliptically polarized electric field transverse to the field B_0. The literature contains various conflicting designations for these two modes. Following Allis (Ref. 5), we designate them as P waves and T waves for the direction of the electric field parallel or transverse to the magnetic field B_0.

If the wave vector $\vec{k}$ makes an oblique angle with the magnetic field $\vec{B}_0$, the proper modes are found by solving Eq. [21] for that value of the angle. In this manner, one can construct wave-normal velocity diagrams which are similar to the ones drawn in Fig. 1. For frequencies below the ion gyrofrequency as well as below the plasma frequency such surfaces are sketched in Fig. 3a. The R and T modes are connected. The P mode does not exist and the wave-normal surface starting from the L mode has a resonance, i.e. the phase velocity becomes zero, for the direction θ_c which can be calculated by setting $n = \infty$ in Eq. [21].

The character of the wave-normal diagrams changes with the sign of any one of the four coefficients K in Eq. [21].

The coefficients K_L, K_T and K_R are positive at $\omega = 0$ and change to negative values passing through poles at ω_i, $\omega_b = \sqrt{\dfrac{\omega_e\omega_i}{1 + \omega_e^2/\omega_p^2}}$ and ω_e. If ω_p is large enough, there will be a frequency interval extending from ω_e to $\omega_L = \sqrt{\omega_p^2 + \omega_c^2/4} - \omega_e/2$ in which all four of the coefficients are negative.

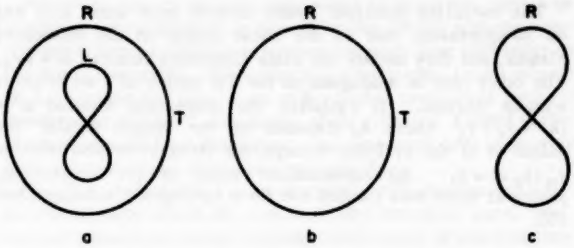

Fig. 3. Wave-Normal Surfaces for Three Values of the Frequency: (a) $\omega < \omega_i$, (b) $\omega_i < \omega < \omega_b$, (c) $\omega_b < \omega < \omega_e$.

The wave-normal diagrams which one obtains, as first the L and then the T waves drop out, are sketched in Figs. 3b and 3c. When R waves also drop out no wave propagation is possible. Varying the ratios ω/ω_e as well as ω/ω_p, one can distinguish thirteen cases which have been categorized by Wm. P. Allis (Ref. 5).

It should be noted that the manner in which the wave velocity surfaces tie either R or L modes to either P or T modes differs from class to class. When, for example, $\omega_L < \omega < \omega_p$, L waves are tied to T waves, differing from the RT tie-up shown in Figs. 3a and 3b.

One can simplify the expressions for the coefficients K in Eq. [22] at sufficiently large frequencies by setting $\omega_i = 0$. This is equivalent with ignoring the motion of the ions, and the resulting waves can properly no longer be classified as MFD waves. There are, however, many similarities between these so called *magneto-ionic* waves and MFD waves, and it is profitable to take advantage of the extensive results which have been obtained in this field. Making the above approximation and setting $x = \omega_p^2/\omega^2$, $y = \omega_e/\omega$, $y_L = y \cos\theta$ and $\tau = y^2 \sin^2\theta/2(1-x)$, one can rewrite Eq. [21] in the Appleton-Hartree form

$$n^2 = 1 - \frac{x}{1 - \tau \pm \sqrt{\tau^2 + y_L^2}}$$

The upper or lower sign apply to the ordinary or the extraordinary mode. Setting $\tau = 0$, one is led to the still simpler quasi-longitudinal (QL) approximation

$$n^2 = 1 - \frac{x}{1 \pm y_L}$$

The assumption of a collisionless plasma for which $\omega_c = 0$ is very often not justified. It is fundamentally not more difficult to consider finite values of ω_c than it was in deriving Eqs. [12] and [13] but it requires more work to carry out the algebra and to present numerical results which involve an additional parameter. By introducing the ratio $z = \omega_c/\omega$ and and redefining $\tau = y^2 \sin^2\theta/2(1 - x - iz)$, one can account for collisions in the complete Appleton-Hartree formula

$$n^2 = 1 - \frac{x}{1 - iz - \tau \pm \sqrt{\tau^2 + y_L^2}}$$

which is discussed in some detail in Ref. 3.

It is considerably more trouble to relinquish the approximation of zero sound speed. To account properly for the influence of thermal motion on the character of MFD waves one must solve the Vlasov equation. By linearizing that equation, one finds that $\vec{j}_1$ at a given point in space depends linearly on the values of $\vec{E}_1$ in the vicinity through a tensor kernel

$$\vec{j}_1 = \int \overleftrightarrow{\sigma}(\vec{r}\,\vec{r}')\, \vec{E}_1(\vec{r}')\, d^3\vec{r}' \qquad [19a]$$

Using Eq. [19a] as Eq. [19] was used before makes the dispersion equations now appear in the form of integral equations. These, in general, cannot be solved rigorously, and one must use approximation methods which differ depending on what phenomena one wants to emphasize. Calculations of such a nature have been carried out by several authors (Refs. 6, 7, and 8).

THE PARTLY IONIZED GAS

In a partly ionized gas like, for example the ionosphere, ions and neutral atoms of the same species are present simultaneously. Charge exchange collisions between such particles occur with very large cross sections because of the resonant nature of this process. These collisions provide a mechanism whereby energy can be drained from the electromagnetic field and the ionized component of the plasma into the neutral component. In addition to the damping introduced in this manner, these collisions also change the Alfvén velocity $V_A = B_0/\sqrt{\rho_0\mu}$. In Ref. (9) it is shown that the modification consists of replacing ρ_0 by an effective density

$$\rho^+ = \frac{n_i m_i}{1 - \dfrac{n_a}{n_i + n_a}\dfrac{\omega_c^{*2}}{\omega_c^{*2} + \omega^2}}$$

where n_a is the number density of the atoms and ω_c^* an effective collision frequency. If ω is small compared to ω_c^* this effective density approaches the total density of the neutral and ionized components taken together. It has been pointed out, however, (Ref. (10)) that the attenuation at low frequencies becomes so large that MFD signals do not satisfy a wave equation. The signal speed is therefore not a perfectly well defined concept.

THE INHOMOGENEOUS MEDIUM

The theory outlined above considers an unbounded homogeneous medium. In applying the results, one must also consider the effect of a space variation of plasma density, magnetic field, and other physical conditions on the propagation of MFD waves. If there are large regions, as measured by the wave length, in which the components of the tensor $\overleftrightarrow{K}$ vary little or not at all, the characteristic modes of the homogeneous medium remain a useful concept. In general, however, the excitation will not be confined to a given mode as in the homogeneous medium, but there will be a coupling causing a transfer between the various modes. Cases of special interest arise if the waves pass through a slowly varying medium, if they encounter an interface and if they encounter a region with a resonance or a cut-off condition where the types of modes change.

THE SLOWLY VARYING MEDIUM

In a slowly varying medium there exist independently propagated waves which closely resemble the characteristic waves appropriate to local conditions (Ref. 11). Under such conditions, wave propagation can be studied by means of geometrical optics. The analysis can be based on Fermat's principle which may be stated in the form

$$\delta \int_0^2 \frac{\cos\alpha\, ds}{v_p}$$

Here ds is taken along the ray path, v_p is the phase velocity in the direction of the wave normal $\vec{k}$, and α is the angle between wave normal and ray. One can also determine the ray path using the canonical equations of Hamilton which have attracted renewed interest because they can be readily integrated with electronic computers (Ref. 12).

BOUNDARIES

A wave which is incident (i) upon an interface between two homogeneous regions will split into a reflected (r) and a transmitted (t) wave. The angles ψ_i, ψ_r, and ψ_t between the three wave normals and the interface normal obey the familiar relations $\psi_r = \psi_i$ and Snell's law $n_t \sin \psi_t = n_i \sin \psi_i$. The amplitude relations follow by matching solutions obtained in the two regions at the boundary. It follows from Maxwell's equations that the normal component of $\vec{B}$ and the tangential component of $\vec{E}$ should be continuous across a boundary. Other conditions depend on the nature of the boundary. For example, the two sides may be separated by a glass wall or there may be a transition region as below the ionosphere where the balance between ionization and recombination processes changes strongly with altitude. When a single characteristic wave is incident on a boundary which separates two different homogeneous regions, it will in general be necessary to include components of the other characteristic wave mode or modes in both the transmitted and the reflected waves, in order to satisfy the boundary conditions (Ref. 13). It is possible for waves to be transmitted through a plasma-vacuum interface; which means that a plasma can emit and absorb electromagnetic radiation.

For laboratory experiments, it is convenient to contain the plasma in cylindrical tubes. In cylindrical symmetry, first-order terms have the form $f_1(r) \exp i(\omega t - kz - m\theta)$. The theory of the hydromagnetic wave guide with a metallic wall and having a uniform axial magnetic field on the inside leads to two types of modes (Ref. 14).

The so-called principal modes involve pure shear flow and no compression, just as the shear modes in the unbounded plasma, and they satisfy the same dispersion relation $\omega = kv_A$. The other type is analogous to the TE modes of a wave guide without plasma. It satisfies the dispersion relation $\omega^2 = (k^2 + k_c^2)\, v_A^2$ where k_c depends on the integer m and the radius a of the cylinder through the Bessel-function relation $J'_m(k_c a) = 0$. An experimental study of the lowest-order principal mode was carried out for a hydrogen discharge (Ref. 15).

TRANSITION REGIONS WITH SINGULAR REFRACTION INDEX

The index of refraction as given by Eq. [21] passes through certain zeros and poles which depend on the ratios ω/ω_e and ω/ω_p. In an inhomogeneous medium the plasma density and the magnetic field depend on the position, and waves traversing such a medium may encounter these zeros or poles. The first situation gives rise to a reflection. In the second case, where a wave encounters a pole, it will be completely absorbed, provided there is some dissipative process. The weaker the dissipative processes are, the narrower is the absorbing layer; however, when they become too weak the wave will be reflected rather than absorbed. The decision between these two alternatives hinges on a detailed examination of the dissipative processes. If absorption is indeed attained this provides an efficient mechanism for heating a plasma by means of radio frequency EM waves (Ref. 16).

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Analytical Methods in Applied Mechanics

(See also Revs. 2322, 2325, 2326, 2327, 2328, 2332, 2337, 2338, 2339, 2340, 2343, 2345, 2352, 2353, 2359, 2368, 2389, 2391, 2399, 2416, 2465, 2473, 2504, 2510, 2547, 2562, 2563, 2635, 2639, 2640, 2641, 2729, 2736, 2743, 2824)

Book—2299. Webb, H. A., and Ashwell, D. E., Mathematical tool kit for engineers, 2nd ed., London, Longmans, Green and Co. Ltd., 1960, vii + 116 pp. 15s.

This book presents—to engineering students and to practising engineers—concise information on the following topics and techniques:

Complex numbers; Differential equations; Uses of the operator D; Macaulay methods; Methods of evaluating integrals; Calculus of variations; Bessel functions; Fourier series; Contour integration; Laplace transform; Theory of errors.

Mathematical rigor is not sought, but the authors try, as briefly and as clearly as possible, to enable the reader to apply the methods rapidly to his own problems, and to give him confidence to extend his mathematical studies when he needs to do so. Many examples are worked in the text and problems are given at the end of the chapters.

From authors' preface

2300. Lee, F. A., A note for finding complex roots of a special kind of quartic equation, *J. Aerospace Sci.* **27**, 9, 714–715 (Readers' Forum), Sept. 1960.

Book—2301. Muir, T., Theory of determinants in the historical order of development, Vol. 1: General and special determinants up to 1841; Vol. 2: The period 1841 to 1860; Vol. 3: The period 1861 to 1880; Vol 4: The period 1880 to 1900, New York, Dover Publications, Inc., 1960, xi + 475 pp.; xxvi + 508 pp. (Four vols. bound as two) $15.

This is a reprint of a well-known classical work. The results are important to the solution of many applied problems. For example, information on recurrent matrices, circulants, etc., are useful to study solution of partial differential equations by finite difference methods.

Y. Luke, USA

Book—2302. Stigant, S. A., The elements of determinants, matrices and tensors for engineers, London, Macdonald & Co., Ltd., 1959, xi + 433. 60s.

One of the complaints frequently raised by those who embark on a study of tensor analysis is that the books dealing with the subject are either too difficult or assume too much prior knowledge on the part of the reader. The author has written other books as well as many papers and has, in one of his books, covered the topics presented in this book. Conscious of the criticism referred to, he has now separated out these topics and presented them anew, very fully and in the most elementary way possible.

The first chapter deals quite adequately with notation and nomenclature, after which the work is divided into three parts. The approach throughout starts from the consideration of simultaneous equations and their solution.

Part I is concerned with determinants and is divided into five chapters. The ground is covered very adequately both as regards the structure and properties and as regards the manipulation of determinants. The text includes many worked examples at every stage and each chapter carries at the end a set of problems for the reader, with answers. No student who goes thoroughly and conscientiously through this part can complain that he does not understand determinants. At the end of it there is a fairly complete bibliography.

Part II deals in like manner with matrices and the organisation of the material is on exactly the same lines. Again there are many worked examples and problems with answers. The text is clear and unambiguous. There is no attempt at this stage to introduce any applications; these first two parts are concerned solely with the techniques of writing and manipulating determinants and matrices, and is put over most efficiently. The bibliography on matrices is also quite adequate.

The important part of the book is, of course, Part III, where the author presents the elements of tensor analysis. Most readers will have studied the earlier parts solely with a view to preparation for the main part.

Here the author has had to change the pattern. He unfolds the mysteries of tensors slowly and clearly and with great skill. He uses practical examples throughout based on stationary electric networks. One misses the exercises for readers at the end of each chapter, but actual worked examples are freely given in the text. Topics which go a little deeper than the elementary approach are kept out of the main text and put into four appendices.

The author's viewpoint is clear. He writes: "what one man can devise another can understand, and the golden key to understanding is...the ardent desire and firm intention to learn.. The mathematically-minded engineer may proceed, therefore, to learn about tensors in the full and certain knowledge that he *can* do so if he *will*". The fact that hitherto some engineers have found insuperable difficulties with the subject he tends to attribute to lack of clarity and other faults in previous writers.

He has set out to prove his point by stripping out the difficulties wherever possible, and by presenting the subject in the simplest possible way in crystal clear language. He has by and large succeeded, but we are bound to ask at what cost? Whenever we undertake to present a difficult subject in words of one syllable we run the risk of over-simplifying, of *suppressio veri*, and other charges. We may be justified in using the principle of diminishing deception but we feel vaguely unhappy about it.

For example when the author describes covariance and contravariance he is both simple and brief. He presents it convincingly to the beginner by saying that if $a = bx$, 'a' is covariant with x, but if $a = b/x$ it is contravariant. But the beginner will hardly realise from this that the contravariant and covariant components of a given vector are not reciprocals of each other and do not necessarily change in opposite ways when the axes are turned through an angle. With regard to changes in "system units" a simple change from (say) feet to inches does not display the difference between contravariant and covariant components as the reader might think from the simple description.

Again, on p. 216, the author defines what he terms a "vector product" AB, where A and B are plane vectors. He shows clearly and rigorously that it remains invariant to a change from rectangular to polar coordinates. But if the X and Y axes are turned through (say) 45° anti-clockwise, although the magnitude of the vector product remains invariant, its direction changes considerably, showing that it is not a true tensor.

Nevertheless, by ignoring such points the author does succeed in what he set out to do, viz., bring the introduction of tensors within the grasp of young engineers being taught in Technical Colleges ahd Polytechnics. His great enthusiasm is revealed in every chapter—the enthusiasm that led him to found the Tensor Club of Great Britain. This is the first really elementary approach to the subject and deserves to succeed. W.J.G.

Courtesy The Matrix and Tensor Quarterly

2303. Duck, W., Estimate of the error for the iteration process of Schulz' for determination of the inverse of a matrix (in German), *ZAMM* **40**, 4, 192–194, Apr. 1960.

When previously known methods are used to estimate the error made in Schulz' iteration process, the required work for this is considerable if the inverse matrix and the matrices of the consecutive steps in the iteration are unsymmetrical.

First, Schulz' original iteration process is described in the article, then the convergence of this iteration method is proved. For the estimation of the convergence error the so-called Neumann's series is used. A numerical example shows the practical application of the method. Reviewer feels that the utilization of Schulz' iteration would be of advantage in the solution of complex structural problems. R. Zsilard, USA

2304. Romanov, M. I., On analytic conditions of aperiodicity in linearized systems (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 5, 162–174, 1959.

Paper actually deals with the question of determining necessary and sufficient conditions to be satisfied by the (positive) coefficients of a characteristic polynome, in order that all its roots be real and negative. Only nonmultiple roots are considered. This implies an aperiodic behavior of all the transients which may set in the linear (or linearized) system described by such polynomes. These conditions, if simple enough, may help to design systems with prescribed aperiodic transients without previously solving their differential equations.

After a brief review of previous work, author obtains these conditions applying well-known theorems of Hermite and Biehler to a certain combination of $f(x)$, the characteristic polynome, and its first derivative. The necessary and sufficient conditions are that the principal minors of the discriminant of a certain hermitic form must all be positive. This requires the evaluation of determinants of order up to n, the degree of the polynome, which is a much better result than many others previously known. Recurrence formulas for the computation of the elements of the discriminant are given, and they are explicitly evaluated for a number of cases. Several numerical examples illustrate the applicability of the method.

W. W. Lubomirsky, Argentina

2305. Levin, J. J., and Nohel, J. A., Global asymptotic stability for nonlinear systems of differential equations and applications to reactor dynamics (in English), *Arch. Rational Mech. Anal.* **5**, 3, 194–211, 1960.

Authors obtain conditions on the damping, spring, and forcing functions of a nonlinear oscillator which ensure that any initial motion approaches equilibrium with time. The spring provides a restoring force sufficient to give infinite strain energy for infinite displacement. The damping is any positive function of time, displacement, and velocity which is bounded and bounded away

from zero. The forcing is a bounded function of time providing a finite total impulse.

Theorem is proven, following a method of Lyapunov, by showing the total energy to be bounded in time. Extension is made to a system of equations arising in criticality studies. The proofs are clear, sufficiently detailed, and interspersed with illuminating comments. C. M. Ablow, USA

2306. Bertram, G., Estimation of errors for the Ritz-Galerkin process for eigenvalue problems: Part 2, Special classes of problems and examples (in German), *ZAMM* **39**, 5/6, 236-246, May/June 1959.

For review on the first part of this paper see AMR **11**(1958), Rev. 2916. In the second part author considers special classes of ordinary eigenvalue problems occurring in engineering science. The lower bounds for the eigenvalues, obtained in Part 1, can here be improved. The rapidity of convergence of the process in the case of these numerically evaluated problems is demonstrated by tables. Author develops also an estimate which enables one to decide how many terms of the process must be taken into account for obtaining a prescribed accuracy of approximation.

R. M. G. Muller, Indonesia

Book—2307. Hilton, P. J., Partial derivatives, London, Routledge and Kegan Paul, 1960, viii + 54 pp. 5s. (Paperbound)

One of a series of concise cheap paperbacks—"Library of Mathematics"—dealing with precisely defined and restricted topics on first- or second-year undergraduate level, this booklet includes: definitions; differentiability and change of variables; implicit functions with derivatives, Jacobians and inverse functions; mean value and Taylor's theorems, maxima and minima. These are set down in form of Theorem-General Proof-Example-Proof-Exercise.

Destined for students using mathematics as a tool, the booklet would have gained appreciably by inclusion of examples involving simple physical facts; a more concise use of words would have favored a wider appeal; the indiscriminate lay-out, a misguided economy, unnecessarily wastes readers' time. Nevertheless, after initial annoyance and extraction of practical essentials, students and those wishing to recapitulate for specific purposes will find this handy source of basic information useful.

M. L. Meyer, England

2308. Albrecht, R. F., Approximation to the solution of partial differential equations by the solutions of ordinary differential equations (in English), *Numerische Math.* **2**, 4, 245-262, 1960.

Consider a partial differential equation (p.d.e.) in two variables x, t. If the partial derivatives with respect to x are replaced by their finite difference approximations, the original system is reduced to a system of ordinary differential equations. This is the usual procedure used to set up p.d.e.'s for solution on an analog computer. For a restricted but important class of problems, error estimates are developed and convergence is proved. The theory is illustrated with three important examples.

Y. L. Luke, USA

2309. Schjødt, R., Difference equations for physical and technical problems (in English), Tekn. Skr., Norges Tekniske Hogskole, Oslo, Norway no. 21 N, 12 pp., 1960.

Paper shows that in certain cases, particularly near irregular boundaries, the finite differential equations do not correspond exactly to those obtained by writing the basic equilibrium conditions for finite elements. Some simple problems are worked using the equations derived from the equilibrium conditions.

Reviewer believes that while the paper shows that the two approaches result in different finite difference equations in certain cases, no conclusive demonstration is given of which approach is correct. It does, however, seem probable that the author's approach is. A recent paper by P. I. Richards ["Numerical stability and unsteady shock waves," *SIAM Rev.* **2**, 3, 208-216, July 1960] appears closely related to the present paper and provides an interesting example. W. Squire, USA

Book—2310. Boole, G., A treatise on the calculus of finite differences, 2nd ed., New York, Dover Publications, Inc., 1960, xii + 336 pp. $1.85. (Paperbound)

Book is an unabridged and unaltered republication of the second and last revised edition, 1872, which was edited by J. F. Moulton.

Ed.

Book—2311. Thomson, W. T., Laplace transformation, 2nd ed., Englewood Cliffs, N. J., Prentice-Hall, Inc., 1960, ix + 255 pp. $10.

This is a good introductory text intended for the use of undergraduate engineers and is based upon the conventional Laplace transform technique.

Text begins with an Introduction and simple review material before taking up the properties of the Laplace transform itself. This is clearly done along with examples and illustrations and then applied at first to simple electrical circuits and then to more complex circuit problems. The elementary dynamical applications (Chap. 4) are then considered.

Structural applications (Chap. 5) have been included here, as they usually are in introductory texts since the beam equation (for example) can be handled. However it is questionable how useful such illustrations are since the Laplace transform technique is best adapted to initial-value problems. It is stated that "In contrast to the classical method, which requires the equations to be written for each interval between loads, the transform method enables any loading to be accounted for by a single equation in terms of the boundary-values at the origin." Not only does the transform technique require (unknown) boundary values at the origin, but it is somewhat misleading to compare the Laplace transform technique with methods that are used very little (if at all) in structural analysis today–when general methods are available which handle such problems efficiently.

The critical load of a column is also handled but with little explanation of the term "lateral instability" or the origin of the governing differential equation and no mention of characteristic values, and so on.

Complex variable theory is briefly presented in Chap. 6 to develop the inversion integral. Further technical applications are: closed loop systems (Chap. 7), including Nyquist diagrams; partial differential equations (Chap. 8) of vibrating strings, longitudinal motion of bars, water hammer, heat conduction, beam vibration, and transmission line theory. The concluding example involves a branch point integration in the longitudinal motion of a bar and is one of the best illustrations in the book since a clear and complete presentation is given for the case of two branch points and a simple pole; it is at this stage that many students find the subject becoming difficult and a presentation of a difficult problem will come as a most welcome one. Several appendices are added, including a short table of transforms.

This text should be useful for an introductory treatment for engineers; occasional misprints have been allowed to mar the appearance (for example complimentary error function for complementary error function, Cauch for Cauchy and Permagon Press for Pergamon Press.) In addition some of the references should be brought up to date. In particular it should be noted that the three volumes of "Electromagnetic Theory" by Heaviside were reprinted in one volume by Dover Publications in 1950 at a moderate price; this makes these classics (which are still very much worth studying) more readily available to the serious student.

F. V. Pohle, USA

2312. Volkov, R. A., The application of a Laplace transform to certain hydrodynamic problems (in Russian), *Inzbener.-Fiz. Zh.* **3**, 4, 65-72, Apr. 1960.

This paper illustrates the application of operational techniques to the problems of vertical liquid flow for two cases. The first case is from a hole in a large vessel and the second is from a pipe with fully developed Poiseuille flow. The conversion terms are included by an Oseen approximation. The reference velocity is taken as the mass velocity from the vessel or tube.

The calculated jet shapes are compared with experimental contours and the radius of the fluid calculated by the Oseen approximation is, at a given distance from the exit plane, about 15 percent less than the measured value.

Aside from an obvious typographical error in the basic equation, the work seems to be accurate.

The belief of the reviewer that any increased accuracy must include the effects of surface tension on the boundary does not detract from this application of Laplace transform theory. It may be of interest to note that the axially symmetric flow problems in this paper are calculated in rectangular coordinates rather than in cylindrical coordinates by use of Stokes stream function. The latter technique does not offer any simplification in the case of flows with free boundaries in an external acceleration field.

E. E. Covert, USA

2313. Smith, R. S., Graphical extension of transform techniques, *Electronics* **33**, 14, 68-71, Apr. 1960.

That numerical evaluation of convolution integrals is a time-consuming process may be attested to by those who have had occasion to carry out such computations on a desk calculator. Although the advent of digital computing machines has all but removed the necessity for such hand computations for sufficiently elaborate problems, many engineers still make less extensive analyses involving the numerical evaluation of convolution integrals. The present paper gives a graphical method for carrying out Fourier convolution calculations. If one is not concerned with highly accurate calculations, the proposed graphical method might be found convenient.

B. R. Parkin, USA

Book—2314. Ledermann, W., Complex numbers, London, Routledge and Kegan Paul, 1960, vi + 62 pp. 5s. (Paperbound)

This pocket book gives the fundamentals of complex numbers theory.

In Chapter 1—the best written—author skillfully builds the axiomatics of complex numbers algebra, just adding one axiom to those underlying real numbers algebra.

Chapters 2 and 3, dealing respectively with geometrical representation and roots of unity, are more conventional, although author smartly derives some theorems of geometry.

Chapter 4 defines exponential, sine, cosine and logarithm functions. Unfortunately, author cannot go on building the theory by way of new axioms and calls for help from another book of the same collection, i.e. "Sequences and series" by J. A. Green.

Very interesting exercises and examples illustrate this nice modern little book.

J. M. Loeb, France

2315. Eckart, C., Variation principles of hydrodynamics *Physics of Fluids* **3**, 3, 421-427, May/June 1960.

Variational principles are used to derive the equations of hydrodynamics. The Lagrangian coordinate system is found more suitable to this type of analysis than the Eulerian. New interrelations between such hydrodynamic results as Bernoulli's principle and the circulation theorem are claimed. The method is also applied to an adiabatic compressible flow in which case the entropy gradients and a "remarkable" quantity defined as the time-integral of the temperature of a particle of the fluid appear. Additional correlation between the analytical and the physical aspects of the derivations would enhance the paper.

E. K. Parks, USA

Book—2316. Forsyth, A. R., Calculus of variations, New York, Dover Publications, Inc., 1960, xxii + 656 pp. $2.95. (Paperbound)

This edition is an unabridged and unaltered republication of the 1926 edition.

Ed.

Book—2317. Martinot-Lagarde, A., Physical similitudes—Examples of applications in the mechanics of fluids [Similitude physique—Exemples d'applications à la mécanique des fluides], Paris, Gauthier-Villars, 1960, 70 pp. $3. (Paperbound)

This is a careful exposition on the nature and use of similarity and dimensional reasoning. The first four chapters are in the nature of an extensive discussion of the subjects, often informal. The fifth chapter is a detailed and formal proof of the Vaschy-Buckingham theorem.

S. Corrsin, USA

2318. Klinkenberg, A., Principles of selecting dimensional systems and units in chemical engineering, *Trans. Inst. Chem. Engrs.* **37**, 6, 335-341, 1959.

Author discusses the philosophy of the selection of dimensional systems and units in engineering and physics and suggests the universal adoption of a consistent and useable system. He compares the situation in the English-speaking countries with that in the "metric countries." After discussing some of the available systems, he states a preference for the adoption of the metre-kilogram (mass)-second-degree Centigrade- ampere- candella system as a practical system. A good bibliography of other books and papers is also presented.

M. L. Baron, USA

Book—2319. Bellman, R., and Hall, M., Jr., edited by, Combinatorial analysis; Proceedings of Symposia in Applied Mathematics, Vol. X, Columbia University, Apr. 24-26 1958; Providence, R. I., American Mathematical Society, 1960, vi + 311 pp. $7.70.

Quoting from the preface; "combinatorial analysis (abbrev.: c.a.) ranges from the studies of finite geometries, through algebra and number theory, to the domains of communication theory and transportation networks." Since the war there has been a revived and growing interest in problems of c.a. Although before the war c.a. problems were already essential in some engineering branches, e.g. in telephone engineering, the main stimulus is in the present-day need for the scientific approach of operational problems in the most general sense.

Due to the discrete character of many practical c.a. problems, many of them were solved by ad hoc methods, and hardly any general technic of sufficient power and applicability was available in the beginning. Nowadays, however, the situation seems to be changing and an outline of such general methods become available and feasible, due to the development of calculating machinery. Just these points make this collection of papers so important and valuable.

Most of the papers are devoted to basic research in c.a., and these are mainly of interest to the specialists in this field. Book contains some very interesting papers of expository character, reviewing applicability and methods. Of special importance are those papers which study the programming for computers to solve c.a. problems.

The papers are divided in four groups: (1) existence and construction of combinatorial design; (2) c.a. of discrete extremal problems; (3) problems of communication, transportation and logistics; (4) numerical analysis of discrete problems.

The book should be in the hands of any one who is confronted with solving c.a. problems. The expository papers will be of great value for engineers who have to deal with the application of opera-

tional research results, mainly to get an idea on what type of problems can be handled. J. W. Cohen, Holland

2320. Aborashitov, R. M., Domain of application of the principle of independent effect of initial errors in the analysis of accuracy of engineering processes (in Russian), *Vestnik Mash.* **39**, 9, 60-63, 1959.

Book—2321. Olver, F. W. J., edited by, Bessel functions: Part 3, Zeros and associated values, New York, Cambridge University Press, 1960, lx + 79 pp. $9.50.

The wide use of Bessel functions makes the appearance of these tables of the zeros particularly welcome. The tables have been printed in the very attractive style which we have come to expect in these volumes of the Royal Society Mathematical Tables printed by the Cambridge University Press. This particular collection (volume 7 part III) is dedicated to the memory of J. R. Airey and the preface by W. G. Bickley aptly observes that "The introduction to the volume tells the story of how these subtle difficulties have gradually been overcome, and this is, in its way, a romance of computation. Like all good romances, the final episode is one of striking success. Here it exhibits the amazing achievement which a computer of genius can attain by the aid of a modern automatic electronic computing machine." The long introduction of 60 pages (C. W. Jones and F. W. J. Olver) ably outlines the methods used to compute the zeros of the Bessel functions and amply justifies the quotation due to Bickley. Important and revealing as this material is in its own right, this review must restrict itself to the tabulated data and its uses.

The main tables are I, II, III. I: zeros of $J_n(x)$, $Y_n(x)$ and the associated values of $J_n'(x)$, $Y_n'(x)$; II: zeros of $J_n'(x)$, $Y_n'(x)$ and the associated values of $J_n(x)$, $Y_n(x)$; for I and II, $n = 0(1/2)$ $20\frac{1}{2}$ and $s = 1(1)\,50$ where $x = j_{n,s}$ is the s-th root of the function of order n; III: zeros of the derivatives of the spherical Bessel functions and the associated values of these functions. The first 50 roots are again tabulated for Bessel functions to order $20\frac{1}{2}$ in steps of 1/2 from 0; all entries are to 8D. Examples: (1) determine the first zero of J_n when $n = 4\frac{3}{4}$ and evaluate J_n'; (2) determine the tenth zero of Y_n' when $n = 1/5$; (3) determine first zero of $J_2(x) + 0.1\,Y_2(x)$. Tables IV and V are tables for easing the evaluation of the asymptotic series for the zeros and associated values for large orders; examples are also given for the use of these tables. F. V. Pohle, USA

Computing Methods and Computers

(See also Revs. 2303, 2306, 2321, 2335, 2341, 2345, 2465, 2498, 2639)

2322. Brakhage, H., Method of numerically treating integral equations using quadrature formulas (in German), *Numerische Math.* **2**, 3, 183-196, 1960.

Paper is concerned with nonsingular integral equations of the second kind. To find an approximate numerical solution of the equation $x(s) + \int_0^1 k(s,t)\,x(t)\,dt - f(x) = 0$ the integral is replaced by a quadrature formula. To solve the resulting system of linear algebraic equations $y(t_i) + \sum_{j=1}^{m} A_j k(t_i, t_j)\,y(t_j) - f(t_i) = 0$ for $y(t)$, the approximation for $x(t)$, might be quite laborious for large m. Therefore author suggests using at first a less accurate quadrature formula (for example with an $m' = (m/2)$) to obtain an approximation $y'(t)$ to the approximate solution $y(t)$, and to improve $y'(t)$ by means of a properly chosen iterative procedure. Investigations are made concerning the convergence of these approximations to $y(t)$. Further, an error estimate is given for the difference between the unknown solution $x(t)$ and any approximate solution $x_n(t)$. In addition, two examples show how the method works and how it compares with other known methods. R. Albrecht, Germany

2323. Richards, P. I., Numerical stability and unsteady shock waves, *SIAM Rev.* **2**, 3, 208-216, July 1960.

Author reports that his attempts to calculate axisymmetric explosions with conventional difference equations, and with time steps determined in accordance with standard linearized stability analyses, have led eventually to negative pressures and densities. To improve computational method he first writes partial differential equations of nonsteady inviscid flow in forms expressing conservation of mass, momentum, and energy. To construct appropriate difference equations that automatically include shock conditions, he advocates numerical simulation of physical conservation laws. For fixed cellular subdivision of space he proposes, as basis of nonlinearized stability analysis, to determine permissible time steps dt so that pressures remain positive. Reviewer finds author's purely heuristic and intuitive development somewhat obscure and not overwhelmingly convincing. However, author reports that applications of his method have yielded good agreement with results obtained by others by more familiar procedures.

J. H. Giese, USA

2324. Miyakoda, J., The method of numerical time integration of vorticity equation involving frictional term, *J. Meteorol. Soc. Japan (II)* **37**, 1, 10-21, Feb. 1959.

First it is proved that the solution for frictional vorticity equation always appears computationally unstable, so far as the usual centered time difference method is used. As the substitute for such method, another method to obtain a computationally stable and accurate solution is proposed. The principle is to apply the centered difference method only to the calculation of the advection term, and to apply the forward difference method in Taylor's series expansion form to that of the frictional term.

From author's summary by H. Arakawa, Japan

2325. Radok, J. R. M., and Merril, R. F., Numerical solution of boundary value problems (in English), *ZAMM* **40**, 5/6, 202-214, May/June 1960.

An explicit method is given for numerical solution of transient physical processes governed by differential equations which under sufficiently smooth conditions permit the evaluation of higher rates of change of the process variables from their space distributions. These processes involve some processes of vital importance to fundamental studies as well as to engineering applications, such as diffusion, wave propagation, flow through porous media, etc.

The method utilizing a finite number of such higher rates of change is presented on the problem of one-dimensional diffusion in a bounded region with radiation into the adjacent medium. Using the difference approximations of partial differential equations, conditions of high-order compatibility between the differential and corresponding difference equations are established. These conditions are shown to ensure a high-order truncation error.

A numerical method for satisfaction of the boundary conditions is presented. Numerical results of four illustrative problems are given. V. Kovarik, Czechoslovakia

2326. Berg, L., Iterations of arbitrary order (in German), *ZAMM* **40**, 5/6, 215-229, May/June 1960.

Every solution $y(s, x)$ of the functional equation

$$y(s, y(t, x)) = y(s + t, x)$$

under the auxiliary condition

$$y(1, x) = \alpha(x)$$

is for natural numbers $s = n$ uniquely defined by the iterates of the function (x)

$$(x) = \alpha(x)$$
$$(x) = \alpha(\alpha(x))$$
$$\vdots$$
$$(x) = \alpha(\alpha_{n-1}(x)) = \alpha(\alpha(\alpha(\ldots\alpha(x)\ldots))).$$

In this paper a direct method not using Abel's equation is given to construct the iterates of a given function. The order of iteration is allowed to take any real value.

A numerical example of the function $f = e^{x-1}$ and order of iteration 1/2 is presented. The convergence of the method is illustrated by this example. V. Kovarik, Czechoslovakia

2327. Fehlberg, E., Suitable transformation of a second-order differential equation for obtaining Runge-Kutta formulae (in German), *ZAMM* **40,** 5/6, 252–259, May/June 1960.

By differentiating a second-order differential equation m times and transforming, Runge-Kutta formulae are obtained which correctly represent the solution and its derivative to order h^{5+m}, where h is the mesh size. A. R. Mitchell, Scotland

2328. Albrecht, J., Rounding off errors in the iteration of $y = \sqrt[n]{x}$ (in German), *ZAMM* **40,** 4, p. 191, Apr. 1960.

A modification of Newton's method of iteration of

$$y = \sqrt[n]{x}$$

is presented. This method reduces the influence of the rounding off errors. Numerical results of an example are given ($n = 3$). They show the influence of the rounding off on the tenth decimal place. V. Kovarik, Czechoslovakia

2329. Putter, P. S., A general maximization process (in German), *ZAMM* **39,** 12, 466–472, Dec. 1959.

A numerical method is described for finding the maximum of a given function under a set of supplementary conditions containing both equations and inequalities. Engineering problems sometimes are of this kind. For instance, the mass of a substance or the Ohmic resistance represent variables which can't assume negative values. The method in question consists in displacing a point in the direction of the gradient of the given function in such a way that the supplementary conditions are satisfied. When these conditions contain more complicated inequalities, author emphasizes that his method still needs improvement. However, for simpler inequalities author's method works very satisfactorily and has already been used for programming on the automatic computer IBM 650.

From author's summary by R. M. G. Muller, Indonesia

2330. Alway, G. G., Multhopp's influence functions and their automatic computation, *Quart. J. Mech. Appl. Math.* **13,** 1, 112–118, Feb. 1960.

Author shows functions required for Multhopp's subsonic lifting surface theory can be expressed as linear combinations of three complete elliptic integrals. Method developed by W. Bartky [*Rev. Mod. Phys.* **10,** p. 264, 1938] has been adapted to produce an iterative scheme (stated without proof) to calculate the elliptic integrals. Author makes empirical comments about rates of convergence, requirements for multiple precision arithmetic, etc.

J. H. Giese, USA

2331. Clenshaw, C. W., and Curtis, A. R., A method for numerical integration on an automatic computer (in English), *Numerische Math.* **2,** 4, 197–205, 1960.

Author proposes to integrate an approximation of the integrand achieved by expansion in series of Chebyshev polynomials utilizing orthogonal properties of the latter with respect to summation. The underlying idea is well known, but various expository remarks bearing on the error and the case of slow convergence should be helpful to many workers. Two illustrative examples are given.

Y. L. Luke, USA

2332. Ambrozy, A., Statistical quality control using an analogue computer, *Meres Es Automat.* **8,** 6, 172–178, 1960.

2333. Fisher, M. E., Limitations due to noise, stability and component tolerance on the solution of partial differential equations by differential analysers, *J. Electronics Control* **8,** 2, 113–126, Feb. 1960.

Analogies

(See also Rev. 2825)

2334. Goland, M., Shear lag solutions for sheet-stringer panels by means of a hydrodynamic analogy, *J. Aero/Space Sci.* **27,** 4, 291–295, 303, Apr. 1960.

An analogy is established between the stress flow in flat sheet-stringer panels and the plane potential flow of an incompressible fluid. The sheet-stringer panels are presumed to be "shear lag" structures carrying essentially longitudinal loads (parallel to the stringers), and the effects of lateral stresses and deflections are ignored.

It is shown that the hydrodynamic analogy consists of a direct relationship between longitudinal stress and the longitudinally directed component of fluid velocity. Shear stress bears a direct relationship to the laterally directed component of fluid velocity. In transferring from the sheet-stringer panel to the equivalent flow, an affine transformation of coordinates, and, hence, of the panel boundaries, must be made.

A discussion is given of the corresponding boundary conditions for the stress flow and the fluid flow. A boundary free of normal stress is equivalent to flow past a solid wall. It is also shown how rigidly constrained boundaries can be dealt with in relatively simple fashion. Problems of reinforcement around cutouts in the sheet-stringer panel are also discussed.

The use of the analogy is demonstrated in several examples, including the stress concentration around elliptic cutouts, with free and constrained boundaries, in large panels under uniform tension. Also studied is the case of a concentrated longitudinal force applied at the center of a large panel.

From author's summary

Note: Author has informed us that an earlier paper by M. Fine, "A method of estimating the direct stress concentration round holes in reinforced sheet," Aero. Res. Counc. Lond. Rep. Mem. 2604, 1942, covers essentially the same material as contained in this paper. Ed.

2335. Kostiuk, A. G., and Sokolov, V. S., About electric modeling of temperature field arising in turbine rotors (in Russian), *Teploenergetika* no. 10, 22–27, Oct. 1959.

Electric modeling described in this paper consists of using strips of electroconductive material whose conductivity and size are related by similarity considerations of the thermal conductive problem at hand. The model described here is capable of solving merely axisymmetric problems, hence its usefulness is rather limited. The paper shows also how to reduce the heat conduction in a complex attachment of turbine blades to an equivalent cylindrical problem.

The method described by authors is quite well established by now in heat-conduction analogies and in that respect, it is felt by this reviewer, it hardly contributes anything new to the field. This reviewer also believes that some other electric analog methods in existence today [See, for example: Max Jakob: "Heat transfer," John Wiley & Sons, Inc. 1949, New York] could be used with greater flexibility than those described by authors.

B. Zarwyn, USA

2336. Potseluiko, V. A., and Trofimenko, A. T., Investigation of the thermal field by the method of electrothermal analogy (in Russian), Investigations of the physical bases of the working processes of furnaces and ovens, Alma-Ata, Akad. Nauk KazSSR, 1957, 242–251; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10265.

Descriptions are given of the application of the method of electrothermal analogy for the solution of the two-dimensional problem regarding the cooling of a trapezoidally shaped rib with third boundary conditions operating, and for the investigation of the temperature field of a cylinder of finite length. The electrical model, made with the help of an electrolyte, enables a solution to be carried out by the method of end differences for the stationary problem of the heat emission of a body consisting of layers with different values for their coefficients of heat emission.

K. K. Vasilevskii
Courtesy Referativnyi Zhurnal, USSR

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 2305, 2415, 2507, 2509, 2625, 2637, 2745, 2754, 2755, 2823, 2827)

Book—2337. Glauert, M. B., Principles of dynamics, London, Routledge and Kegan Paul, 1960, viii + 80 pp. 5s. (Paperbound)

In this little book, the elements of dynamics are concisely treated, using vector analysis. The chapters are: I. Vector algebra; II. Dynamics of a particle; III. Dynamics of a system. There are ten exercises at the end of each chapter, with answers in the back. Topics covered include vector analysis, through the meaning of derivative and integral of a vector, Newton's law, angular momentum, rotating frames of reference (including Coriolis effects), motion under a central force, motion of center of mass, kinetic and potential energy, impulsive motion.

Although author does not go very far (e.g. Lagrange equations, Euler's equations and gyroscopes, vibration problems, are not treated), the topics that are treated are handled exceedingly well in a brief space. The style is quite clear and the logical treatment is careful (e.g. a vector is defined as having magnitude and direction, *and* such that the sum of two vectors is a vector given by the parallelogram law). Moreover, the illustrative examples are usually quite interesting. There is a particularly useful and interesting section on angular momentum of a system of particles. Book could serve as basis for an undergraduate course in dynamics, but additional material from other sources would probably be needed. Book appears excellent for self-study, and for a quick systematic review of the elements of dynamics.

M. Morduchow, USA

2338. Reissig, R., A criteria for asymptotic stability (in German), *ZAMM* **40**, 1/3, 94–99, Jan./Mar. 1960.

Following Yoshizawa [Mem. Coll. Sci. Univ. Kyoto, Ser. A. 29, 27-33, 1955] author uses Lyapunov's discontinuous functions but assumes, in contrast to Yoshizawa, that Lyapunov's function is not monotonic on every curve-solution but possesses jumps in the contrary sense at the points of discontinuity. This paper deals with the establishment of a new criterion related to the asymptotic stability of nonstationary motion. Using certain conditions, the differential equation of the perturbed motion (in vector form) of an n-order dynamic system $x' = f(x, t)$; $f(0, t) \equiv 0$ possesses the asymptotic trivial solution $x(t) \equiv 0$.

The application of the established criterion to the study of damped vibration with forced nonlinear response follows in the form

$$z'' + F(z') + G(z) = E(t) + R(z, z', t).$$

The asymptotic stability of the nonperturbed motion is proved by using one of the two explicitly given Lyapunov functions.

D. Mangeron, Roumania

2339. de Vries, G., Use of complex plane in the study of vibration (in French), *Rech. Aéro.* no. 74, 41–47, Jan./Feb. 1960.

A novel and useful approach is presented which involves the plotting of the complex velocity of a system under forced vibrations. For small damping the loci become symmetrical circles of constant dimensionless frequency and of constant dimensionless damping.

Application of the method is made to the analysis and modification of complicated systems, using both theoretical and experimental techniques; the experimental techniques require an oscilloscope.

E. J. McBride, USA

2340. Balogh, A., Computation of the natural frequencies of torsional oscillations by means of determinants (in Hungarian), *Magyar Tud. Akad. Kem. Tod. Oszt., Kozl.* **25**, 1/4, 177–185, Jan./Feb./Mar./Apr. 1960.

Paper presents a numerical technique for finding the eigenfrequencies associated with the torsional oscillations of a linear system consisting of an elastic shaft with negligible moment of inertia and of n disks. Since the total moment of momentum is constant, one of the eigenfrequencies is zero, and the problem is to evaluate the remaining $n - 1$ roots of the characteristic equation.

The numerical technique is based on transforming the characteristic determinant and finding a simple form of the frequency equation by introducing a systematic and skillful notation for the terms occurring in the expansion. Evaluation of the natural frequencies follows the "chord" method (regula falsi).

Transformation of determinants and expansions are not identical with, but remindful of, Smith's canonical form of lambda matrices.

V. G. Szebehely, USA

Instrumentation and Automatic Control

(See also Revs. 2304, 2497)

Book—2341. Tou, J. T., Digital and sampled-data control systems, New York, McGraw-Hill Book Co., Inc., 1959, xiii + 631 pp. $15.

Of the three books which have recently appeared in the U. S.: J. Ragazzini and Franklin, "Sampled data control systems," McGraw-Hill Book Co., 1958, 331 pp.; E. Jury, "Sampled-data control system," John Wiley and Sons, 1958, 453 pp.; and Tou's text, the latter is the most comprehensive in treatment. The essential content may be characterized as enfolding brief review of continuous data systems; basic theory of sampling and quantization; frequency response analysis of sampled-data systems; z-transform theory, both unmodified and modified; transient response and steady-state analysis; synthesis and optimal design by z-transform and root-loci procedures; error-coefficient analysis; principles of analog-

digital conversion; introduction to finite pulse-width analysis. Of especial note, not occurring in other texts, is an introduction to optimization to a stationary random input by use of the mean-square-error performance index, leading to Wiener-Hopf-type of analysis. A reader especially interested in this last should also look up the complementing paper: J. T. Tou, "Optimum synthesis of linear discrete-data control systems via the modified z-transform method," AIEE District Conference paper No. DP60-640.

The text is clearly written and well-developed in detail. Application of each principal point of theory is illustrated by one, or more, illustrative numerical example (though in check of all of them the reviewer found numerous points that need correction, due possibly to the obtaining of these examples from various sources without checking them for accuracy). Account of theory is correct for the most part—though in common with most control texts enfolding such, the treatment of error-coefficient theory is partly incorrect. A good selection of student exercises affords opportunity for various classroom assignments from semester to semester. A lengthy table of transforms; a long list of major references; and various tables of z-forms, of over-all transforms of specified closed loop systems, and other helpful data buttress the context. In classroom use the reviewer checked nearly every equation, figure, example, and so forth, in detail and found a number of errata. Corresponding corrections, conjoined with the author's findings, are being enfolded in the pending second corrected printing of this widely used text.

In conclusion it may be noted that though all of the mentioned books *in toto* only a small fraction of the total published work on sampled-data systems which is evidenced in more than 500 papers and reports in the reviewer's files (for example, none treat nonlinear systems to any degree, if at all) they yet provide individually or collectively a good introduction to basic linear theory.

T. J. Higgins, USA

2342. Ash, R., Kim, W. H., and Kranc, G. M., A general flow graph technique for the solution of multi-loop sampled systems, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 360–370, June 1960.

Two techniques for finding sampled output are examined: (1) construction of a sampled-signal flow graph; (2) a general gain formula directly applicable to original system. In (1) sampled output can be found (a) by Mason's formula [*Proc. IRE* **44**, p. 920, 1956], or (b) in more complicated systems, problem can be simplified by matrix analysis.

From authors' summary by N. Ream, England

2343. Nesbit, R. A., Incremental phase plane analysis of nonlinear second order difference equations, AFOSR TN 60-616 (Univ. California, Dept. Engng. Rep. 60-28), 29 pp., Feb. 1960.

Nonlinear difference equations arise in the study of sampled data systems. Author makes use of the incremental phase plane (Δ-plane, with as coördinates the variable and its first difference) and develops an isocline method of graphically obtaining the solution to the difference equation. Criteria for the determination of the stability of singular points in the incremental phase plane are given.

The broken line, connecting all successive points of a solution, is called a trajectory. The set of curves tangent to the trajectories are called path tangent curves. They are the phase plane trajectories of a differential equation, which is called "similar" to the considered difference equation, and are useful in the analysis of switching systems, since the switching curve is the same for the Δ-plane trajectories and for the path tangent curves.

The method has the same kind of limitations as the usual phase plane analysis of ordinary differential equations. Moreover, as the author points out, the existence of trajectories is not always assured. Also, as is shown in an example, it seems not always possible to divide the Δ-plane into regions with solutions of the same kind. On the contrary, it seems possible that sets of converging points might be distributed over sets of diverging points. However, solutions of a large class of nonlinear difference equations are readily obtained.

P. De Waard, Holland

2344. Flugge-Lotz, Irmgard, and Lindberg, H. E., Studies of second- and third-order contactor control systems, NASA TN D-107, 122 pp., Oct. 1959.

This is a well-written, informative study of systems mentioned in title with switching according to the sign of a linear combination of the error and its derivatives.

The responses of such systems to chatter operation and to step inputs are studied; the high frequency and D.C. bias errors caused by relay imperfections and other errors caused by filtering lags are discussed; and it is found that under rather wide conditions there is little difference between optimum and linear switching response.

P. G. Kirmser, USA

2345. Kulikowski, R., Synthesis of optimum control systems with area-bounded control signal, *Bull. Acad. Polonaise Sci.* **8**, 4, 179–186, 1960.

Paper is a mathematical treatment of the following control problem: Given that the area over a finite interval, T, under the absolute value of the control signal is bounded, find the control signal such that the output and its derivatives become equal to the input and its derivatives in a minimum interval, T. The problem is derived from missile applications where the control effort is limited by the available supply of fuel for the steering jets.

By applying known methods of functional analysis a general solution is obtained for the linear, time-varying case. Explicit solution is generally very difficult, so that an approximate method is proposed based on a series of uniformly convergent polynomials.

An example of a slowly time-varying system is given where the system weighting function can be expanded in a Taylor series at every instant of time. Practical methods for constructing computer circuits for solving the approximation problem continuously are given.

L. A. Gould, USA

2346. McKee, J. W., A three-axis fixed-simulator investigation of the effects on control precision of various ways of utilizing rate signals, NASA TN D-525, 54 pp., Jan. 1960.

A three-axis vehicle control study has been made by use of a fixed simulator and analog computing equipment, to evaluate the effects of various ways of utilizing rate information. A side-arm controller providing proportional acceleration control was used with a simulated vehicle having no inherent stability or damping. Vehicle rate signals were used to provide control feedback or system damping and were used in the instrument display either separate from or summed with displacement signals.

Near optimum performance of both transitions in roll and control of system disturbance was obtained by using a combination of system damping and summed displacement signals and rate signals.

From author's summary

2347. Cremer, H., and Kolberg, F., Stability analysis by means of the frequency response of controller and controlled plant (in German), *Regelungstech.* **8**, 6, 190–194, June 1960.

Starting from conventional Nyquist criterion for stability of a feedback control system composed of controller and controlled plant, based on frequency response of over-all open-loop system, a criterion is developed for system stability based on frequency response of controller and controlled plant considered separately. Examples are given to show application of general criterion to determine specific criterion for stability of over-all system when either controller or controlled plant is unstable by itself.

T. P. Goodman, USA

2348. Woodling, C. H., and Gates, O. B., Jr., Theoretical analysis of the longitudinal behavior of an automatically controlled supersonic interceptor during the attack phase against maneuvering and nonmaneuvering targets, NASA TN D-454, 45 pp., June 1960.

Report gives results of an extension of the investigation described in NASA TR R-19, in which only nonmaneuvering targets are considered. Both pitch-rate and normal-acceleration automatic control systems are investigated. First-order lead collision navigation was assumed throughout the report.

The results of the calculations, which were performed by means of an analog computer, show the effects of parameter variations of the control system as well as the influence of limiting the rate of elevator deflection of interceptor.

Computed attack runs are presented as time histories and demonstrate clearly the advantages and disadvantages of the different systems considered. The use of high gain and integration in the tracking system as means to respectively reduce and eliminate bias errors was also investigated. No conclusions as to the most desirable system are given. J. Buhrman, Holland

2349. Solukavadze, M. E., Effect of certain typical non-linearities on the adjustment of a mechanical pilot, *Automation and Remote Control* **20,** 5, 529-540, Feb. 1960. (Translation of *Avtomatika i Telemekanika, USSR* **20,** 5, 553-563, May 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

The method of energy balance or equivalent linearization is used to study the stability of simple rolling and pitching motions of an aircraft with automatic pilot having nonlinear elements. Examples are given for limitation of aileron angle in controlling rolling motion and nonlinearities in servo motor controlling elevators in longitudinal motion.

Paper essentially represents particular applications of well-known technique. R. D. Milne, England

2350. Litwiniszyn, J., Flow stability in pipe networks, *Bull. Acad. Polonaise Sci.* **7,** 10, 599-608, 1959.

One of the principal problems during underground fires in mines is to control the flow in the ventilation system. As control valves may become inaccessible and personnel subject to panic in an emergency, an automatic control system would be desirable. This paper considers the stability of a hydraulic network with a control system. By assuming one-dimensional flow and small perturbations the problem is reduced to the conventional one of the stability of a system of linear differential equations with constant coefficients. W. Squire, USA

2351. Dvoretskii, V. M., Determination of the external characteristic and calculation of parameters of a hydraulic compensation regulating unit, *Automation and Remote Control* **19,** 11, 989-993, June 1959. (Translation of *Avtomatika i Telemekhanika, USSR* **19,** 11, 1010-1015, Nov. 1958 by Instrument Society of America, Pittsburgh, Pa.)

Author describes a hydraulic controller with proportional-plus-reset action and derives its transfer characteristics from its mechanical system parameters. Both proportional band and reset rate are adjustable through needle valves. The output range is 0-1.1 kg/cm^2 gage. The principle of operation of this device is very similar to that of conventional pneumatic controllers using bellows, nozzles and vanes. A. W. Gessner, USA

Elasticity

(See also Revs. 2368, 2374, 2375, 2379, 2384, 2398, 2399, 2408, 2417, 2424, 2484, 2487, 2493, 2504, 2703, 2704)

2352. Bhagavantam, S., and Chelam, E. V., Elastic behavior of matter under very high pressures—General deformation, *J. Indian Inst. Sci.* **42,** 3, 29-40, July 1960.

In a previous paper (1960), the authors gave a method of evaluating the effective elastic constants from the expression for the strain energy, utilizing the theory of nonlinear elasticity. In that paper the special case of uniform hydrostatic stress applied to a substance with cubic symmetry was considered. Now the initial finite deformation is assumed to be of a general type, and a general infinitesimal deformation is superimposed. The effective elastic constants for such a case are derived in terms of the second- and third-order elastic constants of the substance in the stress-free state. The effective elastic constants appropriate to a triaxial strain, a uniaxial strain and a shear are derived. F. Chmelka, Austria

2353. Chelam, E. V., Elastic behavior of matter under very high pressures—Simple shear, *J. Indian Inst. Sci.* **42,** 3, 41-46, July 1960.

Following an earlier work of Bhagavantam and Chelam (see e.g. preceding review) which indicates a convenient approach to the problem of elastic behavior of matter under high pressure, present paper deals with the study of the elastic behavior of substances which are initially subjected to a finite simple shear. Expressions are derived for the effective elastic constants in the case of a substance of cubic symmetry. F. Chmelka, Austria

2354. Bufler, H., Rigorous solution for the stresses in a plane composite body (in German), *ZAMM* **39,** 5/6, 218-236, May/June 1959.

Author considers two plane problems. A semi-infinite elastic body is joined along part of its straight boundary either to a rigid stiffener, or to a replica of itself. The state of stress is described by two coupled integral equations for the normal and for the shear along the junction. Solutions are obtained for five different cases of loading. Numerical results are given in the form of plots of reduced variables. Author discusses the singular nature of the solutions at the boundaries of the junction. F. C. Roesler, England

2355. Isida, M., On the tension of an infinite strip containing a square hole with rounded corners, *Bull. JSME* **3,** 10, 254-259, May 1960.

Series solution is obtained for hole in straight or diagonal position. Hole is mapped on unit circle by terms in first and minus third power of mapped variable (hypotrochoidal hole with 4 sides). Method is a development of Howland's, leading to infinite set of coefficient equations. Simple formulas are given for limiting cases of sharp corners. Curves for stress at hole are given for one hole (corner radius of curvature = 1/4 side of square) in straight position, hole occupying up to 0.4 strip width; also curves for diagonal position, with further shapes toward circular limit. Approximate representations of results through "equivalent elliptic hole" are compared. J. N. Goodier, USA

2356. Isida, M., On some plane problems of an infinite plate containing an infinite row of circular holes, *Bull. JSME* **3,** 10, 259-265, May 1960.

Circular holes are uniform and uniformly spaced. Solutions for arbitrary loading on holes, same for each, are found by method of Howland. Stress at hole is given as power series in λ, ratio of hole diameter to center spacing, also maximum stress as curves for λ up to 0.5, for following cases: longitudinal tension, transverse tension, uniform all round tension, uniform shear, tension inclined to row of holes, bending in plane of plate, all with free holes. Also the holes themselves are loaded by internal pressure,

by sine or cosine distributions on half circumference as simplified simulation of rivet loading longitudinally and transversely.

J. N. Goodier, USA

2357. Hayashi, T., On the tension in an orthogonally aeolotropic strip with a circular hole, *Bull. JSME* **3**, 10, 265–270, May 1960.

Circular hole is central. Two complex potentials in two complex variables, usual in anisotropic plane stress, lead to power series. Each coefficient is taken as a power series in γ, ratio of circle diameter to strip width. Coefficients in these series are found by ingenious analysis due to Isida, improving on iteration procedure of Howland's initiatory paper on isotropic strip. In numerical example for oak, stress concentrations are given as first few terms of power series in λ. Stress across minimum section is plotted for $\lambda = 0.316$.

J. N. Goodier, USA

2358. Hayashi, T., On the bending of an orthogonally aeolotropic strip with a circular hole, *Bull. JSME* **3**, 10, 270–274, May 1960.

Application to pure bending of method used by author for tension [see preceding review], with stress results in similar form. Power series in λ are given for constants representing oak. Stress across minimum section is plotted for $\lambda = 0.2$—a small hole at center with small effect on stress.

J. N. Goodier, USA

2359. Engl, W., Stress state due to a series of forces acting in a semi-infinite plane (in German), *ZAMM* **39**, 5/6, 192–198, May/June 1959.

In this highly mathematical paper author discusses two-dimensional stress states represented by a complicated hyper-complex tensor. Besides case defined by title, various limiting forms of the same tensor are investigated and shown to represent known, simpler stress states.

F. C. Roesler, England

2360. Dixon, J. R., Stress distribution around a central crack in a plate loaded in tension; Effect of finite width of plate (with comment by R. K. Penny), *J. Roy. Aero. Soc.* **64**, 595, 439–440 (Tech. Notes), July 1960.

2361. Frid, S. A., Temperature stresses in concrete and reinforced concrete hydraulic structures [Temperaturnye napriazhenya v betonnykh i zhelezobetonnykh konstruktsiiakh], Data on Design of Hydroelectric Developments (IV), HydroPower Stations, Structures and Materials; USSR, The All Union Governmental Design Institute, Moskva, Gos. Energ. Izd-vo, 1959, 72 pp. **$1.**

The publication consists of 7 chapters and 6 appendices and covers the behavior of concrete and reinforced concrete in massive structures, the volume deformations, the temperature stresses during construction and service, discusses construction methods for reducing temperature stresses and the influence of temperature variation on structures, recommends the selection of governing cases for temperature stress analysis of massive statically determinate and indeterminate structures, and discusses methods of analysis taking into account the influence of the creep, of the amount of reinforcement, of the formation of cracks, and discusses the errors encountered in the analysis of structures for the temperature effect. The publication includes numerical examples and 25 references.

Stresses must be analyzed first for shrinkage and temperature for a period of 1 to 3 months after pouring in order to determine the size of pouring blocks. The modulus of elasticity of concrete at one year is almost 1.4 of that at 28 days. This change is important for temperature stress analysis in earlier stages. The second analysis is required to determine the optimum temperature at which statically indeterminate structures must be completed. The third analysis comprises the service period, for which mechanical properties of 6–12-year-old concrete must be used.

Methods of analysis of temperature stresses in free bodies of practical shape are discussed and the temperature functions for the interior of bodies of different shape are graphically represented for practical application.

In the analysis of massive statically indeterminate structures for load and for temperature, when the ratio of height of the element to the span is larger than 1/4, it is necessary to take into account the deformations caused by longitudinal forces N in addition to those caused by moments M. The error neglecting N may be up to 37%; however, in most cases it is less. Normal stress distribution and bending moments caused by loads in massive frames obtained experimentally show that the closest analytical results are obtained using clear span of frames and taking into account in the analysis the three kinds of deformations, i.e., caused by M, N, and shear V. Using spans between center lines, stresses are 2 to 3 times larger. It is recommended to analyze frame for loads and temperatures according to these results. Method of consistent deformations is the most adaptable, because it is difficult, and for sidesway practically impossible, to take into account the N deformations using the moment distribution procedure.

Until recently the temperature stresses were analyzed using elastic theory concept. It is possible at present to apply practically the creeping elastic theory principles. In the period of less than 6–8 years, including construction, the creeping as well as the change of modulus of elasticity with the time reduces temperature stresses in statically indeterminate structures up to 30% and must be taken into account. After 6–8 years concrete is not any more plastic but its strength is higher than 28-day standard, which makes it possible to use higher initial allowable stresses.

The reinforcing, particularly uniformally distributed, makes concrete more homogeneous for stress distribution. The reinforcing increases its tensile strength, but it can not absorb temperature stresses in a free body due to nonuniform distribution of temperatures; it prevents only opening of cracks.

The formation of cracks reduces the rigidity of flexural elements, which may be taken into account by reducing the modulus of elasticity in bending by dividing by 1.5 the standard modulus in compression.

It is essential to take into account the actual temperature changes in concrete, using temperature function for particular bodies, rather than the variations of the temperatures of the air or water. A clear difference must be made between stresses caused by nonuniform temperature in the cross section and those due to the general change of temperature. For a difference in temperature less than 18 °C inside of concrete and on its surface, the cracks do not develop and surface temperature reinforcing is unnecessary. Shrinkage stresses are usually overestimated; normally they do not exceed an equivalent of 5–10 °C.

Neglect of the early creep and of the decrease of the elastic modulus may bring about an overestimate of stresses up to three times in the construction period.

It is desirable, in the writer's opinion, to analyze the temperature stresses more carefully than is often done in designing hydraulic structures. The publication is helpful for this purpose. It is essential to use for stress analysis the temperature function in concrete, which will result in smaller stresses and apparently closer to actual, rather than air and water temperatures. Graphs given in the publication can be used, as well as graphs for creep and variation in elastic modulus. Massive reinforced-concrete structures must be analyzed for load and temperature in a different way from that of elastic bar structures. The paper gives some indication on it but more research is needed. The reinforcing of the massive cross sections should be computed neither on the basis of cracked section assumption nor on ultimate design. A new approach requiring research is needed.

The monograph takes into account the Russian experience in hydraulic structures and is written by a staff engineer of the leading institution in the design of hydropower developments, and is reviewed by its chief engineer, a prominent scientist and designer.
B. S. Browzin, USA

2362. Tremmel, E., Application of the plate theory to the estimation of thermal stresses (in German), *Öst. Ing.-Arch.* **11**, 3, 165-172, Nov. 1957.

Author investigates the thermal stresses developed in a prismatical or cylindrical body with a simply connected cross section under the influence of a two-dimensional time-dependent temperature field. He establishes that the displacement (or strain) potential is mathematically analogous to the transverse displacement of a thin plate which has a shape identical to the cross section of the prismatical body and is clamped all along the edge. Such a plate must be subjected to a transverse load proportional to the two-dimensional Laplacian of the temperature field imposed on the prism. An interesting aspect of this analogy is that the Poisson's ratio μ of the plate need not be specified. If $\mu = 0$ is chosen, however, the stresses s_{xx}, s_{yy}, s_{xy} of the prism become analogous to the moments M_{yy}, M_{xx}, $-M_{xy}$ of the plate, respectively. The obtained analogy is complete in the sense that it allows the results of the clamped plate analysis to be used for the full evaluation of the thermal stresses in the prism without the necessity of superimposing the stress distribution of a disk under the influence of boundary shearing stresses as proposed by Nowacki [AMR **10**(1957), Rev. 3564] in his analogy of the displacement potential to the displacement of a simply supported plate.
G. A. Ziricas, USA

2363. Forray, M., and Newman, M., Axisymmetric bending stresses in solid circular plates with thermal gradients, *J. Aerospace Sci.* **27**, 9, 717-718 (Readers' Forum), Sept. 1960.

2364. Chakravorti, A., Torsion and bending of an aeolotropic beam having a curtate section, *Indian J. Theor. Phys.* **7**, 1, 17-24, Mar. 1959.

The cross section of the beam considered is a curvilinear rectangle bounded by two concentric circles and two radii. Cylindrically aeolotropic material of cubic type, of transversely isotropic type and that with two equal Poisson's ratios are considered.
S. C. Das, India

Viscoelasticity

(See also Revs. 2451, 2454, 2495, 2701)

Book—2365. Bland, D. R., The theory of linear viscoelasticity, New York, Pergamon Press, 1960, vi + 125 pp. $7.50.

Title subject is presented for mathematically trained readers, beginning from one-dimensional case. Combining Voigt and Maxwell elements in different ways it is shown how complex rheological behavior may be represented under various types of loading. Combining a finite number of elements for each rectangular element or "box" of space, author extends theory in a rather abstract manner to three-dimensional cases. Creep and relaxation are described, and sinusoidal response in presence of complex modulus and compliance are explained, introducing normal coordinates. Case of infinite number of elements for each rectangular box naturally leads to retardation and relaxation time spectra. Further chapters deal with stress analysis of special problems. Solutions of oscillation problems are given using complex modulus, and of quasi-static problems using Laplace transforms. Examples of oscillation problems: vibrating reed and Rayleigh waves. Among quasi-static problems treated: expansion of reinforced cylinder by internal pressure, point force on a semi-infinite plane. Also dynamic problems of wave propagation along semi-infinite rods and in infinite space.

Book is considered to be a good but limited review of a widespread literature.
F. K. G. Odqvist, Sweden

Book—2366. Bergen, J. T., edited by, Viscoelasticity: Phenomenological aspects (Symposium sponsored by Armstrong Cork Co., Lancaster, Pa., Apr. 28-29, 1958), New York, Academic Press, Inc., 1960, x + 150 pp. $6.

Book consists of six contributions under headings: Stress analysis for viscoelastic bodies, by E. H. Lee; Linear viscoelastic behavior of rubberlike polymers and its molecular interpretation, by R. S. Marvin; Comparison of viscoelastic behavior in seven typical polymer systems, by J. D. Ferry and K. Ninomiya; Behavior of certain viscoelastic materials in laminar shearing motions, by J. L. Ericksen; Constitutive equations for classes of deformations, by R. S. Rivlin; Stress relaxation of polymeric material in combined torsion and tension, by J. T. Bergen; Normal stress effect in polymer solutions, by H. Markovitz.

Most contributions are easily readible, but sometimes mathematical difficulties involved may only be indicated in passing. Some 150 references are given, all of which with few exceptions belong to past ten years. There are discrepancies of notation on p. 102 and 110, likely to mislead the reader.
F. K. G. Odqvist, Sweden

2367. Bieniek, M. P., and Freudenthal, A. M., Creep deformation and stresses in pressurized, long cylindrical shells, *J. Aerospace Sci.* **27**, 10, 763-766, 778, Oct. 1960.

Creep behavior of thin cylinders under pressure is studied with special reference to distribution of edge moments arising from symmetrical boundary restraints. Well-known secondary creep laws $\dot{\varepsilon} = K\sigma^n$ are used. The generalized three-dimensional law is simplified by plausible assumptions on the interaction of circumferential and meridional strain rates for a deforming cylinder.

It is postulated that behavior will be governed by a modified form of the elastic cylinder parameter such that dependence on the exponent n is introduced. The form and value of this modified parameter is evaluated by finding a deformation pattern which minimizes the appropriate functions of the specific rate of energy dissipation. Author shows peak meridional bending stresses decrease as n increases. Results from one simple experiment are included.
C. E. Turner, England

2368. Hinterleitner, H., Influence of creep on elastically supported plates (in German), *Beton u. Stahlbeton.* **55**, 6, 134-136, June 1960.

Paper notes the serious errors that can result from neglect of the effect of creep. Its effect is shown to be equivalent to an apparent reduction in Young's modulus. Assuming an exponential-type law, the effect is approximated by multiplying the modulus by a certain factor. Graphs illustrate the differences in the shear force and moment distributions before and after this modification.
G. A. Nariboli, India

Plasticity

(See Revs. 2377, 2449, 2453, 2494, 2510)

Rods, Beams and Strings

(See also Revs. 2311, 2364, 2368, 2411, 2414, 2416, 2417, 2421, 2470, 2502)

2369. Kyrklund, H., Determination of bending stresses in bent beams, Acta Polytech. Scandinavica no. 274, 55 pp. (Civil Engng. and Building Construction Series no. 6), 1960.

Object of the work is to simplify the computations of the curved beam theory by the use of the conventional expressions for stresses and a correction factor for the inner fibers of triangular, rectangular, and trapezoidal sections. The following expression is found to be valid with ressonable accuracy

$$\sigma = (M/Z)\ \alpha;\ \alpha = 1 + H(1/r_i + 1/r_m)/6$$

in which H is the height of the profile, r_i and r_m the inner and mean radii respectively. For other sections this formula is found not to be accurate and alternate corrections are proposed. The reviewer doubts whether the approximate methods will result in a worthwhile time saving for most designers.

O. C. Zienkiewizc, USA

2370. Brendel, G., The effective width of plates according to theory and experiments (in German), *Beton u. Stahlbeton.* **55,** 8, 177-185, Aug. 1960.

Author tells of his work on the "T-beams" commission of the European committee for concrete (CEB). This work aims at perfecting the rules for calculating bending of "plate-beams" ("Plattenbalken"). Plate-beams mean girders which are monolithically composed of a plate and one or several longitudinal beams. The effective width (mittragende Breite) is the fictitious width of the plate which is to be used in applying the elementary bending formula.

Paper begins with a discussion of the former work of other authors which deals with the effective width in different loading conditions. Next, author reports experiments made in the Dresden office for testing materials. These experiments first were carried out with beams of reinforced concrete and, later on, continued with models of gypsum, thus reducing the costs. Also, the rules existing in different countries are discussed. Author shows that remarkable differences exist between them. Finally he proposes new calculation rules for engineers' use. These rules will give better consideration to several influences, such as loading condition, effect of continuity at supports, bending rigidity of the compression plate, than do former rules.

E. Monch, Germany

Plates, Shells and Membranes

(See also Revs. 2334, 2367, 2368, 2370, 2405, 2406, 2408, 2409, 2412, 2421, 2463, 2485, 2486, 2501, 2502, 2504, 2513, 2537, 2753)

2371. Hieke, M., Special case of the loaded circular membrane (in German), *ZAMM* **40,** 5/6, 268-274, May/June 1960.

The forced vibrations of a circular membrane acted upon by a time-dependent load on a concentric circular area, or on a concentric circular line, are obtained in form of Bessel functions expressions.

M. G. Salvadori, USA

2372. Hieke, M., A contribution to the eccentrically loaded circular membrane (in German), *ZAMM* **39,** 5/6, 180-192, May/June 1959.

The forced vibrations of a circular membrane acted upon by a time-dependent load on an eccentric circular area are obtained by superposition from the vibrations for the same membrane loaded on a concentric circular area [See preceding review].

M. G. Salvadori, USA

2373. Andreeva, L. E., Determination of the characteristics and the effective area of a corrugated membrane with a hard centre (in Russian), *Naucbn. Dokladi Vyssb. Sbkoly. Masbinostr. i Priborostr.* no. 1, 218-227, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10533.

A round corrugated membrane with a hard disk inserted in its inner part is examined. Fepple's method is used to determine approximately the relations between the flexure and the load, the latter being assumed to be either concentrated at the center of the membrane or distributed evenly over its surface. To begin with, the problem is exactly solved for the case when the membrane is subjected to infinitely small deflections, and the load is determined which produces the assigned flexure at the center of the membrane. The paper continues by approximately determining the load, using Bubnov's method, which will produce the same assigned flexure at the center of the membrane when there is no flexural rigidity in the membrane. The approximate value sought for the load is determined by adding together two previously obtained results. It appears that for a membrane with shallow corrugation, when the relation of the depth of the corrugation to the thickness of the membrane H/b is equal to two, it is possible to disregard the rigidity of the membrane's center in the calculations, provided the relation of the radius n of the disk let into the membrane to the radius of the membrane does not exceed 0.2 to 0.3. For a membrane with deep corrugation, with $H/b = 10$, the rigidity of the membrane's center has little influence on its characteristic even when $n = 0.4$ to 0.5.

I. V. Svirskii

Courtesy Referativnyi Zhurnal, USSR

2374. Kurata, M., and Okamura, H., Bending of a rectangular plate with two opposite free edges and two simply supported edges having any clamped portion (in English), *ZAMM* **40,** 7/8, 310-327, July/Aug. 1960.

The solution is constructed by means of finding the resisting moments introduced along the clamped portion of edge to cancel the slope of the deflection surface produced by a given load only in such portions. Some numerical results of a square plate under a uniform load or a point load have been obtained. Their agreement with experimental data is discussed.

S. C. Das, India

2375. Kurata, M., Bending of simply supported rectangular plates with clamped portions along arbitrary sections of the edges (in English), *Ing.-Arch.* **27,** 6, 385-416, 1960.

The method adopted is the same as that of the preceding review. Numerical results for square plates have been obtained in the cases of (1) a portion clamped in the middle of one edge, (2) same portion as in (1) clamped on every edge and, (3) clamped in the neighborhood of every corner. Agreement with experimental results is shown.

S. C. Das, India

2376. Andra, W., and Leonhardt, F., Influence of the distance between supports on bending moments and reactions in skewed single-span plates (in German), *Beton u. Stahlbeton.* . **5,** 7, 151-162, July 1960.

Skewed plate is free along two opposite edges and point supported (the number of supports varying) along the other edges. Influence surfaces for selected reactions and bending moments are obtained experimentally and are shown. Interesting result is unexpected increase in reaction near obtuse corners with an increasing number of supports.

L. H. Donnell, USA

2377. Hwang, C., Plastic bending of a work-hardening circular plate with clamped edge, *J. Aerospace Sci.* **27,** 11, 815-820, 840, Nov. 1960.

Title subject is dealt with under the assumption that the increments of radial and circumferential curvatures and moments are related by the same incremental laws as for rigid, isotropically work-hardening material in plane stress. Nonlinear differential system is solved numerically for uniform load. Results are given in diagrams and tables.

P. Cicala, Italy

2378. Korolev, A. N., The method of determination of deflections of reinforced concrete slabs supported at the circumference (in Russian), *Beton i Zhelezobeton* no. 3, 138-141, Mar. 1960.

Method applies to slabs after appearance of cracks. As is well known, deflections of slabs in this state cannot be found by the theory of elasticity of homogeneous plates.

Author's method is based on Murashov's theory (1940) of stiffness in bending of reinforced-concrete beams after cracks have appeared, and on the principles of ultimate load design, applied to plates.

The values found by the applied method agree fairly well with experimental results obtained by Bach and Graf (1915).

A. Werfel, Israel

2379. Morgenstern, D., Derivation of plate theory from the theory of three-dimensional elasticity (in German), *Arch. Rational Mech. Anal.* **4**, 2, 145-152, Dec. 1959.

A comparison of the results of a three-dimensional elasticity analysis with those of plate theory is carried out to show that the difference between the stresses calculated from the two theories approaches zero in the limit as the thickness of the plate approaches zero.

B. A. Boley, USA

2380. Sambito, G., Calculation of the oblique plate subject to a uniform load, G. *Gen. Civ.* **97**, 2/3, 150-161, Feb./Mar. 1959.

2381. Borisenko, D. M., Bending of a round plate with one nodal diameter, the plate having a conical contour (in Russian), *Nauchn. Zap. Kievsk. In-ta* **16**, 16, 225-230, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10545.

A solution is given for a differential equation of the fourth order, describing the antisymmetrical flexure of a round plate of linearly variable thickness with a Poisson's coefficient of ⅓. Of four special solutions for the corresponding homogeneous equation three special solutions are determined in elementary functions. The special solution of the nonhomogeneous equation in polar coordinates r, θ with an intensity of the transverse load

$$q = q_0 \left(1 - \frac{x}{r_0}\right) \cos \theta \qquad (q_0,\ r_0 = \text{const})$$

is found in the form of a stepped series.

A. D. Kovalenko

Courtesy Referativnyi Zhurnal, USSR

2382. Gut'erres, P. A., Calculations for round plates under axisymmetrical loading (in Russian), *Nauchn. Zap. Mosk. In-ta Inzh. Vodn. Kh-va* **20**, 15-30, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10556.

The calculation procedure is demonstrated for round plates resting on several annular concentric supports; the method used is that of initial parameters. An equation is derived which is analogous to the known equation for three moments for continuous beams. Tables are furnished of the supplementary functions. Calculations for a plate supported at four points are worked out.

S. D. Ponomarev

Courtesy Referativnyi Zhurnal, USSR

2383. Stiglat, K., and Wippel, H., Plate supported on two adjacent edges and subject to uniform load (in German), *Beton u. Stahlbeton.* **55**, 4, 88-93, Apr. 1960.

Paper is continuation of a former one by same authors: "Die an zwei benachbarten Rändern eingespannte Platte," [*Beton u. Stahlbeton.* no. 7, p. 173, 1959]. Present paper studies numerical solution of rectangular plates with two free edges, one simply supported and the other one built-in or simply supported. Finite difference method was used.

H. Fernandez Long, Argentina

2384. Hoschl, C. A., A thin circular plate on an elastic foundation (in Czech), *Aplik. Mat., Ceskoslov. Akad. Ved.* **3**, 2, 115-123, 1958.

Complicated formulas in mathematical treatment of circular plates resting on an elastic foundation can often be simplified by expressing Bessel functions of a complex variable in polar form. This is done in the case of a circular disk whose edge is acted upon by a uniform shear and by uniformly distributed bending moments.

The real value of the paper lies in applying theoretical results to the approximate determination of stresses and deformations in tube sheets of heat exchangers. Author's considerations are of immediate technical significance and we recommend them to interested engineers.

V. Vodicka, Czechoslavakia

2385. Fischer, K., The inclined position of an elliptical plate on a homogeneous foundation because of an eccentric load with application to rectangular plates (in German), *Bauingenieur* **34**, 7, 258-265, July 1959.

2386. Giencke, E., Analysis of ribbed plates, Parts 1 and 2 (in German), *Stahlbau* **29**, 1, 1-11, Jan. 1960; **29**, 2, 47-59, Feb. 1960.

This two-part paper presents a very thorough theory for plates which are stiffened unidirectionally by cellular ribs and develops method of analysis which gives results in greater detail than usually obtained with other methods. Ribbed floor is reduced to orthotropic plate through rational use of conventional theory for torsion of thin-walled tubes to obtain effective twisting stiffness. Resulting differential equations are solved in series of product forms, generally taking buckling mode shapes of columns for longitudinal functions. Author considers cases in which ribbed floor is hinged at longitudinal edges and supported on both rigid and elastic transverse floor beams.

J. E. Goldberg, USA

Book—2387. Vlasov, V. Z., Thin walled three-dimensional systems (Tonkostennye prostranstvennye sistemy), 2nd revised and amplified ed., Moscow, Gosstroiizdat, 1958, 502 pp. + 234 figures + tables. 20 r.

This is a monograph of outstanding importance and interest to all computing engineers working in advanced problems of the modern theory of thin elastic shells and plates. It deals with such problems, within certain delimitations of the subject, on a very general basis and in a manner directed immediately toward practical applications in engineering. Vlasov has a great name in the newest phases of development of the analysis of shells not only by virtue of the originality of his ideas, but also by a very impressive creative productivity. Before reviewing his monograph under consideration it is, therefore, necessary to say a few words about his work on shells in general, in order to clarify the relation of the present monograph to his earlier books and publications on similar subjects.

A great part of Vlasov's work is devoted to the treatment of prismatic and cylindrical shells. He subdivides such shells into three classes: long shells, shells of medium length and short shells. Long shells are, in his classification, shells for which the cross sections can be assumed to be nondeformable. Shells of medium length are free of longitudinal bending, while the cross sections undergo deformation. Short shells are characterized by bending of the cross sections as well as by longitudinal bending and torsion. The first and the third classes of shells are studied in two monographs which have made Vlasov a celebrated man: "Thin-walled elastic bars" (first edition 1940, second edition 1959), and "General theory of shells and its application in engineering," 1949 (the latter monograph treats of shells of more

general form as well). The second of these two books has never been easily available in this country, as far as known to this reviewer. A theory of shells of medium length is given in the monograph under review.

The presentation starts with development of a "calculational pattern," which permits to state explicitly the essential strain and stress components. The mathematical basis of the theory, or rather of the entire monograph, is a new variational principle introduced (in 1931) by Vlasov and independently of him by L. V. Kantorovich (known in this country as one of the two authors—the other is V. I. Krylov—of "Approximate methods of higher analysis," of which thus far four editions have appeared). The new method permits, in conjunction with the methods used in the structural mechanics for the analysis of statically indeterminate bar systems, to reduce the partial differential equations of the theory of shells to ordinary matrix differential equations. Thus we have here to do with an "indirect" method of the calculus of variations. Its difference from other variational methods can be characterized as follows: the unknown functions are introduced in the form of products of two functions of one variable each; one of these two functions is a known one, the other is an unknown function. Application of the principle of virtual displacements leads to the ordinary differential equations just mentioned. This procedure is equivalent to assuming the shell to have a finite number of degrees of freedom in the direction of one of the two coordinates and an infinite one in the direction of the other.

In addition to the general theory the reader will find in the monograph a complete discussion of a great number of individual modern engineering problems of structural mechanics and applied elasticity of thin-walled systems. The unifying point of view for all of these problems is the uniformity of the variational method outlined above. Thus it happens that the monograph discusses in detail such subjects as application of the aforementioned variational method to the theory of plates, to problems of shell vibrations, stability, thermal stresses, etc. An attempt to enumerate the various engineering problems treated would lead us too far, indeed. Therefore only the headings of the four main parts of the monograph are given: 1. Analysis of shells by means of the mixed variational method, disregarding shear strain, pp. 11–166; 2. Analysis of shells by means of the variational method in terms of displacements with shear strain taken into account, pp. 167–327; 3. Variational methods in the solution of problems in the theory of plates, pp. 328–441; 4. Theory and methods of analysis of beams on elastic foundation, pp. 442–486. To illustrate the breadth of the treatment we add that the latter part also treats the problem of plates, both thin and thick, on elastic foundation (consisting of one and two layers), again by reducing the two-dimensional problems to one-dimensional ones.

Each of the four parts can be studied independently of the others. Paper, print and drawings are comparable to those of the best Western standards. The language is clear, the presentation is lucid, although simultaneous study of some sections of Beliaev's "Resistance of materials," especially a study of its Chapter XXX, will be necessary. It must be stated, furthermore, that a text covering a field of such immense proportions cannot be entirely free of some shortcomings. An example of the latter is offered by p. 52, where the reader finds an incorrect interpretation of the reciprocity theorem as applied to a one-dimensional elastic system. A comparison with Timoshenko's presentation on pp. 351–353 of Vol. 1 of his "Strength of materials," 3rd ed., 1956, where exactly the same elementary problem is treated, will be very instructive for any interested reader.

This remark is not intended to discourage study of this very excellent book; it is a reminder only to study it intelligently, a very general suggestion applying, of course, to any book.

I. Malkin, USA

2388. Fuchssteiner, W., Circular cylindrical shells calculated by means of polynomials (in German), *Beton u. Stahlbeton.* **55**, 5, 106–113, May 1960.

As a simple method of calculating cylindrical shells in bending, the straight-line law of the beam is often used. The author supposes a parabolic dependence of the stresses in the shell section on the central-angle and shows that this method has the same degree of accuracy as the linear hypothesis, but is simpler in the application. He notes that the simplicity of a calculation is more advantageous than the accuracy. L. Foppl, Germany

2389. Kiltschewskij, N. A., Integrodifferential and integral equations for the equilibrium of thin elastic shells (in German), *ZAMM* **40**, 4, 153–161, Apr. 1960.

Paper presents a method for obtaining integrodifferential and integral equations in displacements for thin elastic shells. The method is based on the reciprocal theorem. It differs from Somigliana's method by the special choice of "auxiliary displacements." Due to this choice, the displacement of any point on the middle surface of the shell may be expressed as the sum of the displacement of the corresponding point on the middle surface of an imaginary plate and an additional displacement depending mainly on the curvature. R. Schmidt, USA

2390. Tsurkov, I. S., Bending of closed cylindrical shells by concentrated forces (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 114–123, 1960.

The force is assumed to be of the form $P(z, \beta) = P/\pi R\,[1/2 + \sum_{n=1}^{\infty} \cos n\pi\beta]\,\delta(z - l)$ where R is the radius of the cylinder, z and β the polar coordinates of the middle surface of the shell. This divergent series may be used when the singularities of stresses and stress couples at the point of application of the above force are removed by using the method introduced by Darevskij [*Prikl. Mat. Mekh.* **15**, no. 5, 1951 and **16**, no. 2, 1952; AMR **5**(1952), Rev. 1342]. The solution is given as trigonometric series of β. The terms $n > 1$ of these series are calculated by using Vlasov's theory of shallow shells. O. B. Hellman, Finland

2391. Mishonov, M., Practical determination of bending moments in shells with rectangular plan (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 162–170, 1960.

A study is carried out of a thin-walled shell with constant thickness and constant main radii of curvature. The shell is supported at its circumference by walls rigid in their plane and perfectly flexible outside this plane. It is shown that under certain boundary conditions (restrained or supported edges) it is not necessary to make a preliminary investigation of the membrane state of stress and deflection. By including the boundary conditions in the system of fundamental differential equations of a shell the author converts the problem to the solution of differential equations of a beam mounted on flexible supports. The solution is valid only (near) the shell edges. The author does not deal with the problem of determining torsional moments in the vicinity of corner points of the shell.

The solution of a supported spherical shell is cited as an example. Approximate values of unit edge forces and bending moments are determined. J. Valenta, Czechoslovakia

2392. Burmistrov, E. F., Symmetric bending nonhomogeneous and homogeneous orthotropic shells of revolution with a consideration of large deflections and nonuniform temperature fields (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 185–199, 1960.

General equations of bending of elastic nonhomogeneous orthotropic thin symmetric shells of revolution are written taking into consideration large deflections and nonuniform temperature fields.

An approximate solution satisfying boundary conditions and based on the method of Galerkin is given. Especially the case of a spherical and a conical shell as well as an isotropic homogeneous pleated plate is considered. For the last example a comparison with experimental results is made and author states satisfactory agreement. Natalija Naerlovic, Yugoslavia

2393. Pshenichnov, G. I., On the analysis of latticed shallow cylindrical shells (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 59–65, 1958.

Author considers cylindrical roofs, resting freely upon the end walls hinged along the side walls, which are made of rigidly connected rectangular elements whose sides form spirals which intersect the generators of the cylinder at 45°. In his earlier paper [Reports of the Acad. Sci. of Grusia, no. 4, 1957] author gives a theory for latticed cylindrical shells by reducing the problem to that of a continuous shell, with the basic hypothesis of zero rigidity of the element against twist and against bending in the tangent plane. In the present paper author applies his theory to the case of a shallow shell, using the basic hypotheses of Vlasov's theory of shallow shells. An example shows that the theory gives results which are in good agreement with calculations based on author's general theory.

O. B. Hellman, Finland

2394. Gunnar Andersson, K. E., Cylindrical shell with annular reinforcement and with concentrated loads attaching at the annuli (in Swedish), Institutionen for Hallfasthetslara, Kungl. Tekniska Hogskolan no. 132, 83 pp., 1960.

2395. Isanbaeva, F. S., On the theory of the stability of a fastened cylindrical shell under hydrostatic pressure (in Russian), *Izv. Kazansk. Fil. Akad. Nauk SSSR, Ser. Fiz.-Matem. i Tekbn. Nauk* no. 12, 149–154, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10512.

The initial irregularities in the form of the cylindrical shell are taken to be similar to the expected bending due to the loading; the latter is given by the function

$$w = f_1 \left(\sin^2 \frac{\pi x}{a} \sin \frac{ny}{R} + f \sin^2 \frac{\pi x}{a} \right)$$

where R and a are the radius and length of the shell respectively. The solution is carried out by varying the full energy along the two free parameters f_1 and f and by the number of waves in the surrounding direction n. In so doing a computation was also made for the moment of the symmetrical stressed state. It was demonstrated that this computation reduces the value of the upper critical pressure by 10–15% for a fastened shell without any initial irregularities of form; the value obtained for the lower critical value of the pressure of the above type of shell is practically the same as the upper. The table furnished shows that the initial irregularities in form make the shell more yielding to bending in the first stages of loading but with subsequent loading the reverse effect is produced, by comparison with the shell having no initial irregularities. N. A. Alfutov

Courtesy Referativnyi Zburnal, USSR

2396. Dikovich, V. V., Calculation for a sloping rectangular (in plane) shell of rotation (in Russian), Calculations for large constructions, no. 4, Moscow, Gosstroiizdat, 1958, 393–414; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10517.

A general solution is given of the problem of the equilibrium of the shell described in the title. The solution is based on the work of V. Z. Vlasov ["General theory of shells," Moscow-Leningrad, Gostekhizdat, 1959]. A sloping shell, the middle surface of which represents either a portion of a sphere or the surface of a paraboloid of rotation, is examined. The results of the calculations which characterize the flexures and the stressed state of a sloping shell, square in plane, are put forward.

K. K. Likharev

Courtesy Referativnyi Zburnal, USSR

2397. Sachenkov, A. V., The stability of a cylindrical shell under arbitrary boundary conditions when subjected to even transverse pressure (in Russian), *Izv. Kazansk. Fil. Akad. Nauk SSSR, Ser. Fiz.-Matem. i Tekbn. Nauk* no. 12, 127–132, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10536.

A system of three differential equations in transpositions describing the stability of a cylindrical shell on a small scale is linked with an ordinary linear equation of the fourth order, by making certain omissions, which is elementarily integrated with arbitrary boundary fastenings. In particular, for the case of a shell which is hinge-supported the integration of this equation leads to P. F. Papkovich's known formula [*Byul. Nauchno-tekhn. Kom-ta UVMS.RKKA*, no. 2, 1929]. The critical pressure on a fastened shell or on a shell with one fastened and another hinge-supported edge is 1.5 and 1.25 times higher, respectively, than on a shell with two hinge-supported edges. The field of application of the obtained relationships is practically the same as for Papkovich's formula. In addition, examinations were made of long shells with one free and another fastened or hinge-supported edge and of a shell with two free edges. N. A. Alfutov

Courtesy Referativnyi Zburnal, USSR

2398. Neuber, H., Calculation of stresses in branched tubes (in German), *ZAMM* **39**, 5/6, 213–218, May/June 1959.

Author's general theory of shells, formulated in tensor equations, is applied to calculate stresses in a Y-shaped junction of pipes. Treatment results in a differential equation for a stress function. Analytical solution of this is discussed for special pipe geometries. Reviewer feels that method, although at first sight difficult and abstract, is promising and powerful.

F. C. Roesler, England

Buckling

(See also Revs. 2421, 2423, 2463, 2486, 2504)

2399. Movchan, A. A., The direct method of Liapunov in stability problems of elastic systems, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 3, 686–700, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N.Y.)

Author considers the static and dynamic elastic stability of an elastic beam subjected to constant buckling loads in its plane, i.e. the boundary-value problem

$$\frac{\partial^4 w}{\partial x^4} + \frac{Na^2}{D}\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial t^2} = 0$$

$$0 < x < 1$$

$$t > 0$$

$$w(x, t) = \partial^2 w/\partial x^2 (x, t) = 0; \; x = 0, 1.$$

in terms of various methods of analysis. The usual method of direct integration is compared with a method developed by Lyapunov which defines stability in terms of the function theory of a particular metric space. Author derives various theorems regarding the stability and instability of the motion in terms of the functions of this metric space. The application of this method to stability problems of a more complicated nature is mentioned and references are given. Reviewer finds this paper to be of considerable interest as a different approach to this type of boundary-value problem.

M. L. Baron, USA

2400. Kollbrunner, C. F., Milosavljevic, S., and Hajdin, N., Buckling diagrams for columns with discontinuously changing inertia momentums, Cases 1 and 2 (in German), Mitteilungen uber Forschung und Konstruktion im Stahlbau no. 24, 57 pp., Feb. 1959.

Using the matrix form of writing, transcendental equations for determining critical loads of columns with an arbitrary number of steps are obtained directly. Buckling diagrams relate to columns with three steps with various ratios of step lengths and with various ratios of inertia momentums from step to step. Case 1 corresponds to columns with one end built in and other end free; Case 2 corresponds to columns with both ends hinged.

Two additional cases are considered by the same authors in "Mitteilungen uber Forschung und Konstruktion im Stahlbau" no. 27, p. 47, July 1960.

Case 3 corresponds to columns with one end built in, other end hinged; Case 4 corresponds to columns with both ends built in.

Both papers describe a method on how to use diagrams when the form of the column does not coincide with those for which diagrams are given. Numerical examples are given too. This work is of great value for engineers.

Natalija Naerlovic, Yugoslavia

2401. Kogan, I. Ya., The strength of the turntable columns of tower cranes (in Russian), Calculations for three-dimensional constructions, no. 4, Moscow, Gosstroiizdat, 1958, 57–71; *Ref. Zb. Mekh.* no. 9, 1959, Rev. 10851.

Formulas are proposed for the determination of the critical force in the column of a crane fitted with a guy rope, attached to the tail end of a boom to cover the following cases: (1) loss of stability in the column in the plane of the loads and from the boom's plane with consideration for its turning movement in plane; (2) loss of stability when there is pliability in the fastening of the column and transposition of the point of strengthening of the guy rope. An experimental check disclosed a divergence between the results of the calculation and of the experiment in the range ±28%.

N. K. Snitko

Courtesy Referativnyi Zhurnal, USSR

2402. Gitman, F. E., Investigation of cylindrical columns with prestressed spiral reinforcement (in Russian), *Trudi Nauk-i. In-ta Betona i Zhelezobetona, Akad. Str-va i Arkhitekt. SSSR* no. 3, 204–236, 1958; *Ref. Zb. Mekh.* no. 9, 1959, Rev. 10898.

Ferroconcrete columns were examined: (1) uniform and thick-walled, with different percentages of longitudinal reinforcement in a spiral winding, with different intensities of prestressing in two variants of finish for the surface—with a protective layer and without; (2) thin-walled with a constant percentage of longitudinal reinforcement in a spiral winding with different intensities of prestressing. With a constant outer diameter of the columns of 35 cm, the thickness of the walls for the thin-walled columns was 3.5–4 cm and for the thick-walled 12–13 cm. The uniform columns were made by filling the thin-walled columns with vibrated concrete. The test pressures were developed in presses with powers of 500 to 1000 t. The columns on the press were centered by means of strain gages located in quarters of the length at loads of about one quarter of the loads required for disruption. The measured axial and radial deformations were recorded in the form of graphs while the data for carrying capacity were incorporated in a table.

The author worked out formulae for the calculation of the columns for central compression on the assumption that in the transverse sections of the uniform and thick-walled columns the attainment of plasticity precedes disruption over the whole section, while in the thin-walled columns the diagram representing the stresses in the walls is triangular. Some deductions are furnished which are of interest in both their theoretical and practical aspects.

Yu. A. Shtaerman

Courtesy Referativnyi Zhurnal, USSR

2403. Golushko, P. Ya., Vopilkin, A. A., Sollogub, V. B., and Yurevich, G. G., A test of the experimental investigation of operations with explosives on the stability of the inter-chamber columns in the conditions prevailing in the Solotvinskii salt mine (in Russian), Nauchn. Dokl. Vyssh. Shkoly. Gorn. Delo no. 3, 13–19, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10711.

The total load on the column, the result of rock pressure and of a seismic wave produced after an explosive charge had been fired, is established experimentally. The problem was solved by means of the separate determination of the static load on the column, depending on the rock pressure, and an auxiliary load produced by the force of the explosion. The static load on the column was determined by means of seismic measurements. The auxiliary load on the column due to the force of the explosive charge was expressed through the equivalent magnitude of the static load on the column by the parity of the deformations, evoked by those forces. The data obtained made it possible to establish, for the conditions prevailing, the safe limits for the explosive charges and for the distances between the blast holes, which would avoid damage to the columns.

M. F. Makarochkin

Courtesy Referativnyi Zhurnal, USSR

2404. Basler, K., and Thurlimann, B., Buckling tests on plate girders, Sixth Congress, Inter. Assn. for Bridge and Structural Engng., Stockholm, Sweden, June 27–July 1, 1960; Pap. VI 7, 907–920.

Fifteen ultimate load tests carried out on seven fullsize plate girders show that the classical buckling theory for webs is unable to predict the carrying capacity of such members. The reason for this lies in the fact that a web panel in a plate girder is surrounded by flanges and stiffeners which participate in the functions of the web.

From authors' summary

2405. Massonnet, C. E. L., Stability considerations in the design of steel plate girders, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 1 (*J. Struct. Div.*), 71–97, Jan. 1960.

The collapse by buckling of a web panel having a rigid frame is associated most often with the plastic stretching of the web or with the collapse of the frame. Herewith, the ultimate load is considerably in excess of the critical load resulting from the linear theory of buckling. The problem of finding out reliable design data for a stiffened web panel of minimum weight is too complex to be solved merely theoretically.

Author gives a detailed description of large-scale tests and experimental results obtained during last ten years. Most useful design rules and calculation principles are deduced from these experimental results. For facilitating the numerical application of calculation principles special design charts for webs and for the optimum location of a rigid stiffener have been developed. Author's theory of rational stiffening answers the questions: what are the optimum dimensions for stiffeners and for web thickness, and what is the optimum location of a horizontal stiffener according to the ratio of shearing and normal stresses?

From test results on a girder with unsymmetrical stiffeners author concludes that it is advisable to calculate the moment of inertia of an unsymmetrical stiffener, assuming the effective width of the web no more than 20 t (t = web thickness), diverging from the conventional method.

Further research work on the influence of plate girders with tubular flanges, promising useful practical results, is under way.

E. Seydel, Germany

2406. Thurlimann, B., New aspects concerning inelastic instability of steel structures, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 1 (*J. Struct. Div.*), 99–120, Jan. 1960.

Using a simple column model, author demonstrates that residual stresses can have considerable influence on the inelastic buckling

strength. Residual stresses produce an unequal stress distribution in the cross section of a centrally loaded compressed column. When, with increasing load in any part of the cross section, the sum of residual and loading stresses exceeds the yield stress, the tangent modulus of the stress-strain curve of the column is reduced. In consequence of this reduction, residual stresses which may be introduced by rolling and fabrication procedures lower the buckling load of steel columns in the inelastic range. The reduction depends not only on the magnitude but also on the distribution of these stresses.

Author develops a theory based on the influence of residual stresses. This theory is confirmed by test results and gives an evident explanation of the considerable scatter of test results in the transition range between elastic buckling and yielding of steel columns.

Furthermore, with respect to plastic design methods, author investigates the problem of column buckling in the strain-hardening range, i.e. above yielding stress. Starting from the observation that steel specimens do not deform homogeneously under yield stress but that yielding commences at any weak spot along the specimen and occurs in thin layers forming successively along the length of the specimen, it can be concluded that during yielding part of the material is still elastic, whereas other regions have reached the strain-hardening range. Therefore, for the theoretical investigation of a compressed column with no residual stresses and a sufficiently small slenderness ratio the following assumption is made: in those sections in which yielding has begun, the bending stiffness is reduced corresponding to the tangent modulus at the onset of strain-hardening whereas the bending stiffness of the other portions of the column remains unchanged, i.e. equal to the elastic stiffness.

The relationship between the average axial strain at which buckling occurs and the slenderness ratio is demonstrated graphically for two cases: (a) yielding spreading symmetrically from the middle of the column and (b) yielding commencing from both ends. Theoretical and test results are in good agreement, most test results falling into the scatter range between curves (a) and (b).

Plate buckling in the strain-hardening range is of practical interest, e.g. considering the flanges of an equal leg angle with a sufficiently small width-to-thickness ratio. Similar considerations as in the case of column buckling lead to the assumption of orthotropic plate properties produced by yielding. The orthotropic moduli are determined from theoretical and experimental evidence. The critical buckling stress results from the usual solution of the differential equation of an orthotropic plate. The theoretical results are confirmed by tests.

A comprehensive survey of all column and plate buckling tests is presented by a summary graph, presenting the ratio of buckling to yield stress as a function of the ratio of the actual slenderness ratio to the ideal slenderness ratio corresponding to the yield stress.

Finally a brief summary is given on the extension of analytical and experimental research work to other stability problems such as lateral-torsional buckling of beams and inelastic strength of stiffened steel panels and to recent research work concerning the postbuckling strength of plate-girders [see Massonet, C. E. L., preceding review]. E. Seydel, Germany

2407. Duffy, D. J., and Allnutt, R. B., Buckling and ultimate strengths of plating loaded in edge compression, David W. Taylor Mod. Bas. Rep. 1419, 15 pp., Apr. 1960.

The buckling and ultimate strengths of welded and nonwelded 6061-T6 aluminum plates have been determined. Each plate was simply supported and loaded in edge compression. Ultimate strengths of nonwelded plates were 2 to 15 per cent less, depending upon the b/t ratio, than those obtained by the present Bureau of Ships design procedure. Ultimate strengths of welded plates were 0 to 30 per cent less, depending upon the location of the weld. From authors' summary

2408. Alexander, J. M., An approximate analysis of the collapse of thin cylindrical shells under axial loading, *Quart. J. Mech. Appl. Math.* **13**, 1, 10–15, Feb. 1960.

Author applies elementary simplified analysis to obtain collapse load P of axially loaded thin cylindrical shells, and derives formula $P = C\, t^{1.5}\, D$, where t is the wall thickness, D the diameter and C (~ 6.2 for mild steel) a constant for any one material. He considers only axially symmetrically, concertina-like folding of the walls—a type of deformation associated with the not very thin walls used in the experiments ($t/D > 0.02$). For such cylinders above formula agrees surprisingly well with the experimental results. For thinner cylinders the approach used by Pugsley and Macaulay [AMR **14**(1961), Rev. 1863] would no doubt give better results. D. Williams, England

2409. Bijlaard, P. P., and Gallagher, R. H., Elastic instability of a cylindrical shell under arbitrary circumferential variation of axial stress, *J. Aerospace Sci.* **27**, 11, 854–858, 866, Nov. 1960.

The buckling stress of a cylindrical shell is determined for various circumferential distributions of axial stress. The development is based on small deflection theory, with finite difference techniques being applied to derive the general form of the governing algebraic linear homogeneous equations. The equations are cast in both the determinant and matrix forms, the latter being suitable for the commonly used matrix iteration solution. Numerical results are obtained by means of a high-speed digital computer for cases wherein the stress distribution is described by 32 circumferential elements. It is found that the buckling stress for pure bending, and for more complicated circumferential stress distributions of the axial stress as well, is not much higher than for uniform axial compression. Cases are indicated where small deflection theory is directly applicable.
From authors' summary by G. Gerard, USA

2410. Soderquist, A. B. T., Experimental investigation of stability and postbuckling behaviour of stiffened curves plates, Univ. Toronto, Inst. Aerophys. TN 41, 15 pp. + figs., Sept. 1960.

A series of nineteen flat and curved plates having stiffeners of rectangular cross section have been tested in compression. Measurements made of initial buckling stress and effective widths subsequent to buckling were consistent with previous work. The ultimate strength of the plates was found to increase markedly with curvature, the rate of increase depending on the ratio of stringer spacing to plate thickness.
From author's summary

2411. Kraus, L., Integral equations of thin-walled beams with open, warping-free section (in German), *Ing.-Arch.* **29**, 3, 187–198, June 1960.

Chwalla [*S.B. Akad. Wiss. Vienna*, Abt. IIa, **153**, p. 25, 1944] has established the differential equation which governs the lateral buckling of beams with open simply symmetrical section and thin flanges, subjected to transverse forces. The author shows that, in the particular case of a warping-free profile and if the bending moment follows a linear or quadratic law, Chwalla's equation may be transformed into an equivalent integral equation. Numerical results, obtained by solving this equation, are given for cantilevers or simply supported tee beams subjected to various loading conditions. C. E. Massonnet, Belgium

2412. Peterson, J. P., Correlation of the buckling strength of pressurized cylinders in compression or bending with structural parameters, NASA TN D-526, 21 pp., Oct. 1960.

An empirical procedure is used to establish a correlation between test data from recent NASA reports [AMR **10**(1957), Rev. 99, and AMR **13**(1960), Rev. 5745] and shell geometry for cylinders subjected to compression and to bending. The empirical equations for buckling stress are in reasonably close agreement with most of the data considered. Author states: "The correlating procedure should prove useful in future shell-buckling investigations by reducing the number of tests required."

D. O. Brush, USA

2413. Huffington, N. J., Jr., The response of missile structures to high velocity longitudinal impact, Martin Co., Weapons Systems Div., Baltimore, Md. RR-17, 58 pp., Nov. 1960.

The problem of dynamic buckling of columns has been investigated, with emphasis on the case of high-speed impact where significant variation of axial load along the axis may be expected. A formulation for the dynamic buckling of an axisymmetrically deforming cylindrical shell is also presented. For both of these problems, the equations of motion are a set of coupled nonlinear partial differential equations. Finite difference solutions are presented for the column, both for the case where the effects of transverse shear deformation and rotatory inertia are included and for the case where these effects are neglected. The importance of these effects is partially assessed by means of numerical examples, in which a free-ended column is subjected to a half-sine wave compressive pulse of high intensity and short duration.

Additionally, a variational energy method for approximate solution of the dynamic buckling problem is developed and applied to the case of an initially straight, semi-infinite column which is simply supported at the finite end.

From author's summary

Vibrations of Solids

(See also Revs. 2339, 2344, 2427, 2442, 2497, 2624, 2734, 2761, 2764, 2816, 2817)

2414. Shamanskii, V. E., and Shevelo, V. N., On longitudinal vibrations of an elastic string (cable) of variable length (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 65-71, May/June 1959.

The longitudinal vibrations of a cable carrying a car in a vertical mine shaft are calculated for deep shafts. The weight, elasticity and internal damping of the cable as well as the weight of the car are considered. The dynamical equation with appropriate boundary conditions is solved by the Galerkin method. A displacement function is used which is assumed to be a product of the statical displacement of the cable under its own weight and that of the car, multiplied by an unknown function of time. Simplifications are made and the result is an ordinary nonlinear differential equation of the second order. An approximate solution is obtained assuming the car to travel first with uniform acceleration, then with constant velocity, and then to be uniformly decelerated to rest.

E. Saibel, USA

2415. Francia, G., Self-excited vibrations with contact friction (in Italian), *ATA* **12**, 1, 43-61, Jan. 1959.

Frictional damped vibrations can be studied from two points of view: (1) The investigation of the causes of the produced forced vibrations; and (2) the study of the effects produced by frictional damping. In the first part of the paper author describes the analytical treatments of these phenomena, presenting the equations of motion, the stability conditions and the dynamical instability. In the second part he gives the experimental results for various cases of vibrations (e.g. string vibrations, the vibrations of the body pulled on the floor, etc.), with very interesting photos and diagrams. These results and their validity are discussed.

D. Raskovic, Yugoslavia

2416. Bogdanoff, J. L., and Goldberg, J. E., On the Bernoulli-Euler beam theory with random excitation, *J. Aero/Space Sci.* **27**, 5, 371-376, May 1960.

Authors consider a simply supported beam acting according to the Euler-Bernoulli beam theory. The beam is subjected to random external disturbances and its motion is damped by continuously distributed external damping forces. The theory which is developed provides for exciting forces which are either deterministic or random in space and random in time. The paper demonstrates that, contrary to other recently published conclusions, the mean square displacements and stresses are finite in all cases in which the total power of the time-varying excitation is finite. The authors contend that in the cases examined, and for assumptions on the random excitation which are physically plausible, the Bernoulli-Euler theory with distributed external viscous damping predicts finite mean square displacement and bending stresses.

R. L. Bisplinghoff, USA

2417. Fryba, L., Vibrations of an infinite elastically supported beam subject to the action of an untrue wheel (in German), *ZAMM* **40**, 4, 170-184, Apr. 1960.

Author investigates the influence on the rail of irregularities of the wheel or rail, in particular that of a flat spot on a wheel, and gives a bibliographic history of the problem. Exact statement of the problem includes a clear statement of simplifying suppositions; the car is considered as a system with two degrees of freedom and and the problem is considered as one of forced vibrations of an infinite beam on an elastic foundation. A system of four equations is derived and solved by means of Laplace transformations. An integral equation of the Volterra type is obtained and solved numerically. The solution agrees with experimental results.

O. Bottema,

2418. Shkenev, Yu. S., Vibrations of tensioned bars (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **27**, 81-86, 1960.

Transverse elastic vibrations of a slender bar in tension are computed. A solution of the nonlinear differential equation is assumed in the form

$$y(s, t) = \sum_{1}^{\infty} w_n(t)\, \varphi_n(s).$$

In the case of free vibrations $w_n(t)$ are expressed by elliptical Jacoby functions, whereas the approximate solution of forced vibrations is treated by the small parameter method. By substituting special values for w_n we get some known simpler cases, e.g. vibrations of elastic strings (zero flexural rigidity) or vibration of an unstressed beam on fixed hinge supports.

The solution is applicable to many practical problems. No numerical examples are given.

V. Petrovsky, Czechoslovakia

2419. Kabulov, V. K., Investigation of the vibrations of beams of constant section with the aid of integral equations of the equilibrium type (in Russian), *Vychisl. Matematika* no. 3, 138-148, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10582.

Integral equations are derived for the vibrations of a beam by applying the theorems on the change of momentum and the moment, also by using the known Timoshenko correlations for the deflection moments and intersecting forces. The solution of concrete problems is effected with the assistance of characteristics. An approximate solution is obtained by using the method of iteration for the case of an infinitely long beam loaded with a concentrated

force. The case of a cantilever beam whose end is transposed in accordance with the given principle is investigated; here curves are drawn for the forms of vibrations for different moments of time.

Ya. S. Uflyand
Courtesy Referativnyi Zhurnal, USSR

2420. Kutukov, B. N., Some problems in static and dynamic computation of regular systems (in Russian), Calculations for spatial constructions, no. 4, Moscow, Gosstroiizdat, 1958, 203-238; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5508.

The following problems are scrutinized: (1) the natural vibrations of a filament supporting several equal concentrated masses, disposed at identical distances from each other; (2) the natural torsional vibrations of a straight shaft, carrying several masses which possess equal moments of inertia relative to the axis of the shaft and which are disposed at equal distances from each other; (3) the natural deflection vibrations of a beam with equal masses, disposed at equal distances; (4) the static computations for a system consisting of inter-crossing beams, where the girders laid in a certain direction are at co-equal distances from other girders laid in that direction; and (5) the natural deflection vibrations of the inter-crossing regular system. The investigation is based on the customary methods used in modern dynamics of construction, but with account being taken of the regularity of building-up of the systems being investigated. The consequences are that when determining the frequencies the necessity for direct determination of elementary transpositions is dispensed with, the secular equation is replaced by a transcendental equation, the derivation and solution of which are relatively simple. The paper gives an instance of examining the case of disruption of the regularity of the system.

N. I. Bezukhov
Courtesy Referativnyi Zhurnal, USSR

2421. Simon, G., Effect of torsional rigidity of stiffeners on the buckling loads and the natural frequencies of rectangular plates with stiffeners placed parallel to boundaries subjected to Navier boundary conditions (in German), *Stahlbau* **29**, 7, 207-215, July 1960.

There are well-known methods by which one may, with relatively little effort, determine approximate buckling loads and natural frequencies of an edge-stiffened rectangular plate with Navier boundary conditions, provided only the bending stiffness of the stiffeners is considered. In this paper, a method based on the Rayleigh-Ritz procedure is developed to determine buckling loads and natural frequencies of plate-stringer combination including torsional rigidity of stiffeners of typical cross section. Expressions for strain energy and kinetic energy are derived. Results are given in tables and in graphs.

For a typical system, results indicate that a saving of 8% of the web surface (web plate + stringers) is obtained on the basis of including torsional rigidity.

A. P. Boresi, USA

2422. Shteinvol'f, L. I., The insulation of massive foundations against vibrations (in Russian), *Trudi In-ta Mashinoved. Akad. Nauk SSSR, Seminar po Teorii Mashin i Mekhanizmov* **17**, 68, 40-50, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10923.

The title subject is investigated for the case when buffers have been placed in position between the portions of the foundation above and below the springs. A value was obtained for the coefficient of the buffer η in relation to the stiffness of the buffers and the correlation of the machine's mass and the portion under the springs. It is established that the case where η can change in the limits $+\infty > \eta > 1$ has substantial advantages (in comparison with the case where $-\infty < \eta < 1$), since here the buffering occurs with an arbitrary correlationship of the stiffnesses and always proves to be the larger. The author gives the method for the calculation of the parameters of the buffering system for the case of a variable frequency of the exciting force and a recommendation for the extension of this method to include the case of setting unbalanced machines on elastic beams. For this case an approximate solution is proposed by substituting for the system "elastic beam-above-the-springs portion" a dynamically equivalent system of concentrated masses, set on springs.

A. A. Gusarov
Courtesy Referativnyi Zhurnal, USSR

2423. Naumov, K. A., Stability of a thin-walled tube under the action of a longitudinal periodic force with consideration for damping (in Russian), *Trudi Vses. Zaoch. Energ. In-ta* no. 11, 56-61, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10592.

Axially symmetrical forms of the vibrations of a cylindrical tube are investigated; the tube is subjected to axial loading which changes periodically with time. A dissipative term is introduced into the equation; this term contains the first derivative of the transposition by time; this is followed by the usual substitution which leads to the Matier equation with a dissipative term. The boundaries of the regions of instability for this equation are discussed.

V. V. Bolotin
Courtesy Referativnyi Zhurnal, USSR

Wave Motion and Impact in Solids

(See also Revs. 2311, 2413, 2488, 2489)

2424. Craggs, J. W., On two-dimensional waves in an elastic half-space, *Proc. Camb. Phil. Soc.* **56**, 3, 269-285, July 1960.

The waves of the title are examined under the assumption of dynamic similarity, in which the components of stress, strain and material velocity depend only on the variables r/t, θ/t (r, θ cylindrical polar coordinates, t time). Analytic solutions are given for following problems:

I. A constant surface traction is applied over the part $\theta = 0$, $0 < r/t < V$ (V constant) and the rest of the half-space is free from stress. Numerical results are quoted for the case $V \longrightarrow \infty$.

II. A concentrated line load, with direct and tangential components increasing linearly with time, is applied for $t > 0$ to the surface over the line $r = 0$.

The half-space is initially at rest.

R. Nardini, Italy

2425. Davydov, S. S., Vibrations of a nonhomogeneous soil in an elasto-plastic state, the result of a momentarily applied load (in Russian), *Sb. N.-i In-ta Osnovanii i Podzemn. Sooruzh. Akad. Str-va i Arkhitekt. SSSR* no. 32, 119-163, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5575.

For the purpose of his investigations on the propagation of elasto-plastic waves in soils the author proposes to use the results published on this subject by Kh. A. Rakhmatulin [*Prikl. Mat. Mekh.* **9**, no. 1, 1945] and by the abstractor [*Prikl. Mat. Mekh.* **10**, 5, p. 6, 1946]. The exposition of these results in a somewhat rearranged form takes up the first seven paragraphs of the paper. In paragraphs 8-14 there is a generalization for the case where the compression modulus (corresponding to the modulus of elasticity in metals) of the soil appears to be variable with depth. That being so the velocity of propagation of the waves in the limits of the linear portion of the compression graph will represent a given function of the depth. The compactness of the soil and its limit of flow, however, are assumed to be constants. A wave for the removal of the load is derived and an approximate solution is examined for the case when, during the shedding of the load, the modulus of elasticity is equal to infinity.

Numerical examples are worked out which show that when determining stresses in a sandy or clay soil the account taken of the

variability of the compression modulus is an entity. Here attention has to be drawn to the fact that these theoretical results, on which the author relies, refer to the propagation of single-component waves of stresses in bars; the author however investigates plane waves, corresponding to single-component transpositions and to a three-dimensional stressed state. The question of deriving formulas in the theory of plasticity for soils in similar conditions, and also of taking into account the variability with depth of the limit of flow and compactness, is not referred to in the paper.

G. S. Shapiro
Courtesy Referativnyi Zhurnal, USSR

2426. Durasov, A. S., Controlling the quality of concrete by the impulse method (in Russian), Dokladi Mezhvuz. Konferentsii po Ispytaniyam Sooruzh. (Reports of the Intercollegiate Conference on Testing Constructions), Leningrad, 1958, 225-235; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 11033.

Methods are investigated for determining the stability of the characteristics of concrete by means of the velocity of propagation of the visco-plastic properties to ensure a more precise evaluation of the strength of the concrete's degrees of quality. Apparatus was designed for the impulse tests: a type IPV-1, for determining the elastic properties of the concrete by the velocity of propagation of an elastic wave, and a type AM, which evaluates the nonhomogeneity and the visco-plastic properties of the concrete as well by means of the distortion of the leading front of a complex elastic signal.

Yu. I. Likhachev
Courtesy Referativnyi Zhurnal, USSR

2427. Bolotin, V. V., Statistical theory of earthquake resistance of structures (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 123-129, July/Aug. 1959.

This article is an attempt to provide a theory giving an adequate representation of the effect of seismic action on structures. It deals mainly with the presentation of the seismic action using a statistical approach. This is based on a generalized acceleration of the form

$$a_{k(t)} = A_k\,(q_1 \ldots q_n)\,\varphi_k\,(q_{r+1} \ldots q_m,\, t)$$

where q_i are random parameters, $A_{k(t)}$ is a determinate function of time (the envelope of the acceleration curves depending on parameters $q_1 \ldots q_2$) and $\varphi_{k(t)}$ a stationary random function of time. The theory applies to linear systems but could be extended, with some generalizations, to nonlinear systems.

J. Solvey, Australia

Soil Mechanics: Fundamental

(See also Revs. 2425, 2434, 2436, 2460)

Book—2428. Berezantsev, V. G., Computation of foundation soil strength [Raschot prochnosti osnovanii sooruzhenii], Leningrad, Gosstroiizdat, 1960, 138 pp. 4 r 15 k.

Author studies deformations and displacements produced by foundations in soil masses as a function of the relative foundation depth ("r.f.d.") (i.e., depth to width ratio $b:b$). For medium and well compacted sands there are the following situations:

—for r.f.d. less than 1.5-2, the soil mass failure occurs by driving out the soil from beneath the foundation. The sliding surface for r.f.d. less than 0.5 has a continuous form; if r.f.d. exceeds 0.5, the sliding surface presents a breaking point above the foundation level. In both cases, the values of the critical pressure and of the corresponding settlement are small enough to be taken into account for constructions.

—for r.f.d. values greater than 1.5-2, settlements corresponding to critical pressures become very large, inadmissible for structures. For this reason, author proposes that for r.f.d. from 1.5-2 to 3-4, the soil strength be characterized by the load corresponding to the development of the sliding zones formed under foundation on both sides, up to the ground level. For increasing loads, the sliding zones extend upwards, causing a rapid increase of the settlements.

—for r.f.d. exceeding 3-4, the settlements caused by compacted and sliding zones under the foundation reach very great values, so that the soil mass strength criterion is no longer valid.

Author presents computation methods, auxiliary tables, diagrams and examples for each of the three mentioned cases. The computation methods are based on the limit state theory (in the form proposed by V. V. Sokolovsky for the plane problem developed by the author for the spatial axisymmetric problem) and on author's findings concerning deformations and sliding displacements in the soil.

The great majority of the material presented refers to compacted sandy soils; some indications pertaining to clayey soils are also given.

R. J. L. Bally, Roumania

2429. Laletin, N. V., Calculation of nonlinear deformation of soils in the bases of constructions (in Russian), Proceedings of the 4th International Congress on Soil Mechanics and Foundation Engineering, Moscow, Akad. Nauk SSSR, 1957, 253-260; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10665.

The necessity is emphasized of application of the nonlinear relation of the deformation to the stresses in soils when calculating the settling of constructions. Formulas are given for the approximate determination of the settling of ribbon and round foundations with consideration for the nonlinear relation of the settling to the load. The theoretical results are compared with the results of observations on settling in tall buildings in Moscow, stamps, assemblies of piles, and also with the results of observations on the horizontal transpositions and twist in the foundations of masts. The closeness of the theoretical and experimental data is noted.

V. G. Berezantsev
Courtesy Referativnyi Zhurnal, USSR

2430. Trollope, D. H., and Chan, C. K., Soil structure and the step-strain phenomenon, *Proc. Amer. Soc. Civ. Engrs.* **86**, SM 2 (*J. Soil Mech. and Foundations Div.*), 1-29, Apr. 1960.

Author presents an hypothesis regarding structure of a composite soil, i. e. random distribution of coarse grains within a colloidal matrix. Under shear stresses the colloidal particles assume orientation parallel to direction of impending failure, and coarser grains migrate to the zone of failure so that further shear resistance is mobilized. By this mechanism the author seeks to explain his observation of a series of steps in the stress-strain curves, a phenomenon he terms "step-strain."

Tests conducted by the author confirm above hypothesis by showing absence of this phenomenon with pure clays. Sustained-load (static fatigue) and repeated-load (dynamic fatigue) tests showed loss of strength in soils exhibiting step-strain but no effect in pure clays.

In view of statistical considerations reviewer doubts whether the suggested mechanism of the build-up of grain structure in the failure zone would account for the discontinuities in stress-strain curves.

J. Glucklich, Israel

2431. Lomize, G. M., The compacting of clay soils by electrical means (in Russian), *Nauchn. Dokladi Vyssh. Shkoly. Stroitel'stvo* no. 1, 93-103, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10370.

An investigation is carried out of the one-dimensional problem of the packing of a water-logged soil which is under the action of the differences of potential of a direct current. It is assumed that the velocity of motion of the water in the interstices of the soil depends in this particular case on the gradients of the hydrostatic

pressure, the intensity of the electrical field and the humidity of the soil, and can be described by a linear relation analogous to the d'Arcy relation. On the basis of the customary assumptions made in the theory for the packing of an earth medium, an equation is obtained for electro-packing and its solution is applied to several initial and boundary conditions. The fact is noted that the theory evolved and the experiments made show good agreement. V. P. Sipidin

Courtesy Referativnyi Zhurnal, USSR

Soil Mechanics: Applied

(See also Rev. 2779)

2432. Bolcskei, E., Application of shell-structures for foundations (in English), *Acta Techn., Acad. Sci. Hungaricae, Budapest* **28**, 1/2, 199–207, 1960.

Author illustrates the economic applicability of various forms of shell-structures for foundations. The presented inverted shell forms may be well applied in foundation design. The omission of extensive formwork and shuttering as necessary for roof-shells and the easy shaping of earth excavation to the desired form coupled with the considerable saving in construction material as compared to other foundation structures are apparent advantages of this new idea.

No questions of actual dimensioning or those of the force-play are dealt with in this article; the author mentions only the importance of considering much bigger loads, bending, and stress concentrations in singular points. (This statement refers also to our previous review, AMR 13(1960), Rev. 1788.) In order to clear up this problem elaborate experiments have been started.

C. Szechy, Hungary

2433. Stanescu, E., Calculation of load capacity at groups of piles (in Hungarian), *Mélyépítestudományi Szemle* **10**, 4, 172–175, Apr. 1960.

Considerations relating to the transmission of forces between pile surface and soil, the relative displacement being the essential quantity. The character of the skin friction distribution depends mainly on stratification. Author points out that the results of model tests can hardly be related to real piles. As to the bearing capacity of pile groups, he cites the requirements of the Roumanian standards, giving values for pile efficiency smaller than 1.

A. Kezdi, Hungary

2434. Chen, F. H., The earth pressure on retaining wall with surcharge during earthquake (in Chinese), *Chinese J. Civ. Engng.* **6**, 11, 944–958, Nov. 1959.

Coulomb's theory [see, for example, Taylor, "Fundamentals of soil mechanics" Chap. 17] is used to calculate lateral earth pressures on retaining wall with sloping back, sloping backfill, uniform surcharge and earthquake forces. The effect of earthquake is accounted for by an earthquake coefficient. Analytic formulas and tabulated numerical coefficients for active and passive earth pressures are given. M. L. Pei, USA

2435. Gamalunov, A. I., Ice pressure on inclined walls (in Russian), *Gidrotekh. Stroit.* **29**, 6, 42–43, June 1959.

Ice is similar to a semi-infinite plate resting on an elastic medium if it is acted upon at its contact with the wall by an uniformly distributed vertical load (which is the vertical component of ice pressure upon the wall). The maximum bending moment in the ice plate is determined and then equated to the maximum which the ice may undergo; thus the maximum vertical load component can be established. Using this component and the friction coefficient between wall and ice, the horizontal ice pressure on the wall and the dragging force of the ice plate moving along the wall may be calculated. By a similar reasoning author shows that the bending effect is more dangerous than shear for the ice plate.

With the aid of the critical bending moment the ice "pull out" effect on the wall is computed when the water level decreases and the ice plate remains suspended.

R.-J. L. Bally, Roumania

2436. Borodin, P. V., Experience in closure of river channels in USSR (in Russian), *Gidrotekh. Stroit.* **29**, 8, 5–11, Aug. 1959.

Russian hydraulic engineers gained considerable experience in building of rock-fill dams in running water. Twenty-one closures were performed in 1935–1959. Paper describes 15 recent closures, methods applied, material used and conditions of work. A method advanced by S. V. Izbash, admitting free seepage and storage, proved to be particularly successful. Several tables contain very interesting summaries of data. Author maintains that closure of very wide rivers is definitely possible.

S. Kolupaila, USA

Processing of Metals and Other Materials

(See Rev. 2684)

Fracture (Including Fatigue)

(See Revs. 2360, 2430, 2442, 2452, 2453, 2489, 2511)

Experimental Stress Analysis

(See also Revs. 2496, 2500)

2437. Peters, R. J., Wax model construction, Nat. Res. Counc. Canada, MET Rep. 257, 3 pp. + figs., Sept. 1960.

This report describes the manufacture of wax models in the Ship Laboratory and gives notes on their limitations.

From author's summary

2438. Richards, T. H., Stress distribution in pressurized cabins: An experimental study by means of Xylonite models, Aero. Res. Counc. Lond. Curr. Pap. 503, 17 pp. + figs., 1960.

This report is concerned with the effect of openings on the stresses in plain, pressurized circular cylindrical shells. A review of relevant theory is presented and the design, construction and testing of Xylonite models is described.

Results are summarized and discussed, and conclusions, together with proposals for future work, are presented.

From author's summary

2439. Arcan, M., and Tannenbaum, M., Photoelastic model studies on cracked reinforced concrete beams (in English), *Rev. Mécan. Appl.* **5**, 4, 545–554, 1960.

Paper examines the possibility of photoelastic studies on reinforced-concrete beams after the formation of cracks.

Models made of Dinox F 110 and reinforced with steel wires or strips glued by a cold setting Araldit D adhesive, with perfect and reduced bond, were used to study the state of stress near and between cracks. M. Soare, Roumania

2440. Pirard, A., Remarks on Moiré method in photoelasticity (in French), *Rev. Univ. Mines (16)* **9**, 4, 177-200, Apr. 1960.

Author describes a new method for determining the sum of the principal stresses in a point of a plane stressed model with the aid of Moiré fringes. In the first part he gives a general survey of the mathematical background underlying the origin of the Moiré pattern and a clear exposition of the determination of Moiré fringes arising from different families of generating curves.

Applying these basic principles to a plane model of small constant thickness, illuminated by a monochromatic light source in the stressed and unstressed state, author concludes that the lines of constant value of $(\sigma_1 + \sigma_2)$, the so-called "equal sum fringes," will arise as Moiré fringes originated by the difference of the interference lines, which are caused by the thickness variations of the stressed model.

In part two he derives and discusses the conditions for the validity of a fringe as "equal sum fringe." How the stresses σ_1 and σ_2 are determined separately from the classical isochromatics for the stress differences $(\sigma_1 - \sigma_2)$ and the "equal sum fringes" $(\sigma_1 + \sigma_2)$ is treated in part three, together with an elegant graphical method showing how calibration difficulties are to be eliminated. The whole method is a supplement to the classical photoelastic treatment. The experimental set up is very simple in its essence and does not call for a great extension of the usual photoelastic equipment. The use of a rather thin ($\frac{1}{8}$-in.) model for the Moiré pattern is advised. These matters and the study of a nontrivial example, fully worked out, are the subject of part four and five.

Possibly the treatment of a well-known example, e.g., the tension bar with a hole, and comparison of the results by this method with other well-known methods would have thrown some light upon its accuracy. Reviewer considers method to be a very elegant experimental way for the solution of an old problem.

J. J. P. Geerlings, Holland

2441. Gilev, N. K., A photoelectrical strain gauge for measuring the torsion moment (in Russian), *Zavod. Lab.* **25**, 1, 119-120, 1959; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 11080.

A description of the instrument given in the title is furnished; the gage is used for following the process of cutting wood. The apparatus is based on the change of angle of the twisting of a shaft proportionately to the transmitted moment on some portion of it which forms the base of the device. The angle of twist is measured with the aid of photoelements by turning two disks with slots in one corresponding to those in the other. The actual torsion moment is determined as the difference between the magnitude of the torsion moment being measured and the magnitude of the torsion moment used up in overcoming the forces of friction in the bearings produced by normal forces and obtained in dynamic calibration. The measurement error is 3 to 5%.

V. D. Kopytov
Courtesy Referativnyi Zhurnal, USSR

Material Test Techniques

(See also Revs. 2370, 2447, 2764)

2442. Forney, D. M., Jr., Acoustical fatigue test procedures, *Noise Control* **6**, 1, 11-21, 49, Jan./Feb. 1960.

Paper is an excellent review; it describes early history, devices used, general results and analysis used. Characteristics of existing siren generators are listed. Wide land sirens, air-stream modulators, engines in test cells and cold air jets are discussed as sources. No verified scaling law exists, so tests are at full noise level. Life for random excitation is greater than for discrete frequency excitation at same noise level. Opposite is true for constant rms stress. No agreement exists on use of normal versus grazing incidence tests. Results also depend on how panel is attached. Some investigors usually monitor noise level; others adopt panel displacement. Analysis has used Miner's linear damage rule and Rayleigh stress distribution. Theory of Miles is widely used. All problems are by no means solved.

V. Salmon, USA

2443. Tsobkallo, S. O., Slavskil, G. N., and Chetyrkina, N. A., A new apparatus for the measurement of the modulus of elasticity of material in sheets (in Russian), *Izmerit. Tekhnika* no. 1, 24-27, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 11081.

A method worked out by the authors for the above measurements is described; also the principle of action of a new device for measuring the modulus of elasticity at high temperatures during deflection of comparatively thin (with thicknesses of 0.1 to 0.8 mm) sheet material possessing great flexibility. First place is given to the vibrational method of measurement, consisting of the determination of the natural frequency of the vibration of the test sample. With dimensions for the sample (as regards length) sufficient to guarantee the required precision of the measurements, the natural frequency of the vibrations of the test sample becomes infrasonic, which eliminates application of the customary acoustic methods of measurement, which give extreme precision. In the new apparatus use is made of low frequency vibrations. The sample to be tested is in the form of a flexible strip of rectangular shape. The basic error when measuring the modulus of elasticity of thin sheet materials was found to be mistakes in the measurement of the thickness of the test samples, which varied in regard to their length. In relation to the quality of the material and its thickness the modulus of elasticity was determined with a relative error of 0.5 to 1%. However, the value of E_t/E_0 can be determined with a relative error of less than 1% even in the most unfavorable conditions.

Yu. G. Maksimov
Courtesy Referativnyi Zhurnal, USSR

2444. Regel', V. P., Berezhkova, G. V., and Dubov, G. A., New apparatus for micromechanical testing and its use for the investigation of the mechanical properties of polymers (in Russian), *Zavod. Lab.* **25**, 1, 101-105, 1959; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 11070.

A description is given of the improved apparatus for testing (at temperatures of from -70 to $+600\,^\circ$) microsamples for tension and compression with the use of a photoelectric dynamometer. The device is especially suitable for plastics with a modulus of elasticity less than 1000 kg/mm^2; it is also suitable for polymers of the rubber type. Examples are furnished of the curves for compression and relaxation stresses for polymethylmethacrylate, "eskapon" and rubbers. The difference in the magnitudes of the limit of forced elasticity in tension and in compression is emphasized. The various advantages of the new apparatus are enumerated: the rigidity of the apparatus, the work done in tension and compression, the small size of the samples (for solid polymers, 2-3 mm in diameter; for rubber-like polymers, less than 10 mm) which requires small quantities of material for testing, etc.

Yu. S. Lazurkin
Courtesy Referativnyi Zhurnal, USSR

2445. Papers presented at the Symposium on Statistical Methods of Material Testing, Zurich, Germany, Jan. 22, 1960; *Schweiz. Arch.* **26**, 7, 257-294, July 1960.

2446. Agerman, E., Notch sensitivity in steel (in English), *ASEA Res., Sweden* no. 4, 5-46, 1960.

Properties of Engineering Materials

(See also Revs. 2446, 2448, 2513)

2447. Stowell, E. Z., and Heimerl, G. J., Predicted behavior of rapidly heated metals in compression, NASA TR R-59, 15 pp., 1960.

A phenomenological relation previously proposed for a metal in tension at elevated temperatures is applied to compression under rapid-heating conditions. Predictions are made of the behavior of 7075-T6 aluminum-alloy sheet in compression under unrestrained constant-stress conditions and under completely restrained conditions for temperature rates from 0.1° F to 100° F per second.

From authors' summary by M. Holt, USA

2448. Peters, R. W., Wilson, R. G., and Wallio, M. A., Characteristics of a 60-inch arc-image furnace and application to the study of materials, NASA TN D-505, 19 pp., Oct. 1960.

An arc-image furnace consisting of two paraboloidal searchlight mirrors 60 inches (152 centimeters) in diameter and a modified electrode mechanism has been developed and has been used as an operational piece of laboratory equipment for the study of the elevated-temperature behavior of engineering materials. Using two types of 16-millimeter high-current anodes and operating in the atmosphere at current levels of 80 to 550 amperes, the arc-image furnace provides a heating-rate range from 100 to 1000 Btu/ft^2-sec (27 to 270 cal/cm^2-sec) with good reliability and reproducibility. Running times vary from 60 seconds at 550 amperes to 10 minutes or longer at the lower current levels.

From authors' summary

2449. Ross, A. S., and Morrow, JoDean, Cycle-dependent stress relaxation of A-286 alloy, *ASME Trans.* **82** D (*J. Basic Engng.*), 3, 654-660, Sept. 1960.

When an axial fatigue specimen is subjected to repeated strain cycling about a fixed mean strain value, the mean stress decreases with the number of strain cycles. To explore this type of material behavior, tubular fatigue specimens of A-286 alloy have been axially tested under conditions of controlled strain, and the cycle-dependent relaxation of mean stress measured. Fatigue data for five initial mean stresses are also reported. It was found that, in the case of A-286 alloy, most of the relaxation occurred early in the fatigue life, especially during the first ten cycles.

From authors' summary

2450. Trofimov, V. I., The procedure adopted for the experimental investigation of industrial steel in the elastoplastic stage during its biaxial stressed state (in Russian), Dokladi Mezhvuz. Konferentsii po Ispytaniyam Sooruzh. (Reports of the Intercollegiate Conference on Testing Constructions), Leningrad, 1958, 156-152; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10969.

The procedure is described for the investigation of the biaxial stressed state on plane samples. In the case of two-sided compression, square plates were used 80 × 80 mm and a thickness of 14-16 mm. In the case of two-sided tension, cruciform samples were used. The measurements were made within the limits of the square crosspiece of the cross to which portions were joined fitted with a row of narrow slots, parallel to the direction of the forces. The tests on the mutual action of the compression and tension forces were carried out on strips 800 × 40 × 16 mm. Details are given of the experimental equipment and the procedure used in the tests is described. It should be noted that the adoption of the procedure described enabled up to 7 to 8 tests to be made on one sample.

B. M. Broude

Courtesy Referativnyi Zhurnal, USSR

2451. Fisher, W. A. P., A parameter to represent the mechanical properties of aluminium alloys after soaking at elevated temperatures, Aero. Res. Counc. Lond. Curr. Pap. 506, 21 pp. + figs., 1960.

Test data on the tensile mechanical properties of two structural aluminum alloys after heating for long periods at fixed temperatures are correlated on the assumption that the degree of over-aging can be expressed by the value of the 0.1 per cent proof stress at room temperature after heating.

Rate process theory is applied to show that the time t (hours) and the absolute temperature T (°K) are related by the formula $T(C + \log_{10} t) = B$, where B has the same value for various conditions of over-aging, but the term C is a single-valued function of the condition.

Curves are plotted for RR.58 clad sheet showing the change in proof stress, at room temperature and at the soak temperature, for fixed times at various "soak" temperatures.

By using the above formula, extrapolated curves for 10^4 hours or longer can be obtained. This affords a basis for advance project study for the employment of this or other aluminum alloys for supersonic aircraft.

The value of the activation energy for the over-aging process is deduced.

From author's summary

2452. Dunsby, J. A., Some experiments on the effect of time at temperature on the room temperature reversed bending fatigue characteristics, and on the tensile strength of 24S-T alclad aluminum alloy, Nat. Res. Counc., Canada, MS-102, 21 pp., Aug. 1960.

Experiments are described in which specimens of 24S-T aluminum alloy were held at temperatures of 400 °F or 300 °F for periods ranging from 1½ to 100 hours prior to conducting room temperature reversed bending fatigue or tensile tests. The physical properties of the material change radically with such treatments and it is shown that these changes can be correlated for varying times and temperatures by the use of the Larson-Miller parameter.

The results of the tensile tests are in good agreement with previously reported tests provided that proper allowance is made for the initial condition of the material. It is shown that these earlier tests can be used to determine the effects of time at temperature on the tensile strength on a given sample of this material provided that the initial yield strength is known.

From author's summary

2453. Zhukov, A. M., Properties of a titanium alloy under a complex stress state (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **28**, 220-223, 1960.

Eleven tubular samples (wall thickness, 0.365-1.015 mm; average radius, 14.2-14.7 mm; and ratio of radius to wall thickness, 14.4-39) of alloy VT1D (0.05C, 0.3 Fe, 0.15 Si, 0.15 O, 0.04 N, 0.01 H, balance Ti) were tested. Only five fractured in the plastic range: 2 in simple tension in the longitudinal direction; 1 in simple tension in the circumferential direction; and only two in a special apparatus under complex stress state (k, ratio of the axial to the circumferential stress, equal to 2 and 3). The latter two broke at very small plastic deformations. Remaining six, 1 under simple transverse stress and 5 under complex stress, all with $k \leq 1$, broke in the elastic range. Results indicated the nonhomogeneity of the alloy and the presence of elastic anisotropy as well as a highly cold-worked initial state.

Results were insufficient for a comparison of plasticity in service with test conditions. The author concludes that if the radial stress is small and if the cracks along which fracture proceeds are at 45° to the main tensile stress then one can take as a qualitative first approximation $\tau_{max} = \sigma_b/2$ where σ_b is the yield strength in uniaxial tension.

Anna M. Turkalo, USA

2454. Murphy, A. J., and Kennedy, A. J., Temperature effects on material characteristics, Coll. Aero. Cranfield, Rep. 135, 17 pp. + 10 figs., Aug. 1960.

Some of the physical properties of the main elements of interest in high-temperature technology are reviewed. Some general trends emerge when these properties are viewed as a function of melting point, but there are a few notable exceptions. Titanium, zirconium, niobium and tantalum all have disappointingly low moduli; chromium is excellent in many ways, but has a limited ductility at lower temperatures; molybdenum oxidizes catastrophically above about 700 °C, and niobium suffers from severe oxygen embrittlement. Beryllium and carbon (in the graphitic form) both stand out as exceptional materials, both have very low densities, beryllium a very high modulus but an unfortunately low ductility, while graphite has a relatively low strength at the lower temperatures, although at temperatures of 2000 °C and above it emerges as a quite exceptional (and probably as the ultimate) high-temperature material. Some of the fundamental factors involved in high-temperature material development are examined, in the light, particularly, of past progress with the nickel alloys. If a similar progress can be achieved with other base elements then a considerable margin of useful high temperatures is evidently a factor of major concern, not only with metals, but with graphite also. Successful coatings are therefore of high importance, and the questions they raise, such as bonding, differential thermal expansion, and so on, represent aspects of an even wider class covered by the term "composite structures." Such structures appear to offer the only serious solution to many high-temperature requirements, and their design, construction and utilization has created a whole series of new exercises in materials assessment. Matters have become so complex that a very radical and fundamental reassessment is required if we are to change, in any very significant way, the wasteful and ad hoc methods which characterize so much of present-day materials engineering. From authors' summary

2455. Mathauser, E. E., Stein, B. A., and Rummler, D. R., Investigation of problems associated with the use of alloyed molybdenum sheet in structures, NASA TN D-447, 60 pp., Oct. 1960.

The results of an experimental study to explore the capabilities and limitations of thin Mo-0.5Ti molybdenum-alloy sheet for structural applications at high temperatures are presented. Evaluation tests at temperatures ranging from room temperature to 3000° F were made on resistance-welded corrugated-core sandwiches that were coated with a commercially available oxidation-resistant coating known as W-2 and on coated oxidation and tensile specimens. The performance of the corrugated-core sandwiches in compressive strength and static oxidation tests, tensile properties of the coated molybdenum sheet, and the life of the coated specimens in static oxidation tests are given. A description of the equipment and procedures utilized in performing the evaluation tests is included. From authors' summary

2456. Special reinforcements of reinforced concrete and of prestressed concrete (wires and bars). Symposium of "La Réunion Internationale des Laboratoires d'Essais et de Recherches sur les Materiaux et les Constructions" (RILEM), Liège, 2-5 July 1958 (in French and in English), Bull. Centre Étude Constr. Genie Civ., 1958, 947 pp.

Contributions to the symposium are divided into the following three sections.

Subject I. Special reinforcement for ordinary reinforced concrete. Fairly complete data on the requisite properties of American, Belgian and German reinforcing steels and the Norwegian and Swedish requirements for Kam steel 40, 50 and 60. Tables include allowable stresses. Brittle fracture, particularly at low temperatures, and requirements for a minimum diameter of curvature are discussed.

The last recommendations of the European Concrete Committee for the design of reinforced-concrete sections are extracted. As to the question of crack formation in reinforced-concrete structures, references are made to the Stockholm Symposium of the RILEM in 1957.

Subject II. Prestressed wire and bars: The essential problems discussed are homogeneity of the characteristics of the reinforcements, toughness of the material or the absence of fragility, choice of the prestress—this choice is partly related to the economic factor and partly to a safety condition to ensure sufficient prestress—loss of stress due to relaxation, and absence of defects and liability to corrosion under tension.

According to the General Reporter the reports contain material necessary for drawing up specifications and it was proposed that the RILEM should be responsible for this work.

Subject III. Methods of binding special reinforcements, prestressed wires and bars to the concrete or to one another: Anchorage systems for cables, currently used in France and in Germany in the prestressing processes, are described, and their essential particularities are given. Strength properties in the different structure elements are explained. Furthermore, testing methods used for joinings and a few test results are given. Anchorages and joinings of wires are discussed. T. A. Odman, Sweden

2457. Kosaka, Y., A study of effect of ratio of height to width of concrete specimen on the compressive strength, *Technol. Rep. Osaka Univ.* **10**, 97-107, Jan. 1960.

The effect of the ratio of height to width of concrete specimen on the compressive strength was investigated by means of the theoretical analysis as the statically determined plain plastic problem. Consequently, it was found that this effect of the compressive strength of concrete specimen could be explained quantitatively by the analytical result of plastic stress which was carried out by applying the yield criterion of cycloid type.

From author's summary

2458. Rabinovich, A. L., Shtarkov, M. G., and Dmitrieva, E. I., Methods used for the determination and magnitudes of elastic-constant glass textolite at high temperatures (in Russian), *Trudi Mosk. Fiz.-Tekhn. In-ta* no. 1, 115-144, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5865.

Three methods are described for the determination of the elastic constants at temperatures up to 200 °: with the aid of Martens' apparatus, the use of strain gages for resistance, and the frequency method. Measurements were made of the moduli of elasticity and of Poisson's ratios for the glass textolite mark KAST-B. This material is laminar and anisotropic and, consequently, the mechanical properties are ascertained for several directions. The following data are published: the relation of the modulus of elasticity to the direction of the fibers at room temperature, the relation of strength to the direction of tension at room temperature, the influence of repeated loading on the magnitude of the modulus of elasticity, the relation of stress to deformation for different directions in functions of temperature, the relation of the modulus of elasticity and Poisson's ratio to the temperature for various directions, and so forth. A comparison of a few data found by using different methods shows that the proposed methods appear to be more or less of equal value. The results of comparison between the calculated and the experimental values for Poisson's ratio lead to the deduction that glass textolite mark KAST-B may be looked upon as an orthotropic body even at a high temperature.

S. A. Ivanov
Courtesy Referativnyi Zhurnal, USSR

2459. Kimball, K. E., Effect of thermal gradients on the strength of phenolic and silicone reinforced plastic laminates, U. S. Dept. Agric., For. Prod. Lab., Rep. 1878, 22 pp., Sept. 1960.

Phenolic and silicone laminates 1/8 inch thick were investigated to determine: (1) The thermal gradient present when various conditions of boundary temperatures were maintained; (2) the time required to reach this steady-state thermal gradient; and (3) the effect of the thermal gradient on the compressive strength properties of the laminates.

Data on the three phases of the study are presented in tables and figures. In general, it was found that (1) for all practical purposes, the thermal gradient is a straightline relationship between the boundary temperatures; (2) the time required to reach a steady-state thermal gradient can be a matter of seconds in 1/8-inch-thick phenolic or silicone glass laminates, depending on the boundary conditions and intensity of heating media; and (3) compressive strength decreases as the difference in boundary temperatures is increased. The compression tests were all made parallel to the warp and after a 10-minute soak at a given test temperature.

Approximately 200 thermal gradient and compression tests were made during the study. An analysis of the thermal strains in a member subjected to a thermal gradient is presented.

From author's summary

Book—2460. Ruppeneit, K. V., Some questions dealing with the mechanics of rock strata (in Russian), Moscow, Ugletekhizdat, 1954, 384 pp. + illus. 12 r 35 k; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5636.

The author applies the methods of the mechanics of a continuous medium to the investigation of massive rock formations which has been weakened by mine workings. He comes to the conclusion on the basis of the experimental data that, in relation to homogeneity and constancy of mechanical properties, rock is in no way inferior to the majority of constructional materials to which, ordinarily, the methods of the mechanics of a continuous medium are applied. The greater part of rock formations, apart from clayey schists, can be looked upon as isotropic. The condition of strength for rock has a form in good agreement with the arc of a cycloid passing over to a straight line tangential to it. The calculation formulas obtained, subject to the condition of the plasticity of this form, have a sufficiently simple structure. Problems are investigated on the joint work of the pit-prop and the rock formation for drift mine workings, on the distribution of stresses in a massive around an isolated unreinforced mine working, and on the stressed state of overhead chambers and unworked virgin rock blocks.

A. I. Govyadinov

Courtesy Referativnyi Zhurnal, USSR

2461. Lenskii, V. S., Influence of radioactivity on the mechanical properties of solid bodies (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **28**, 97–133, 1960.

Numerous experimental data show that irradiation noticeably changes physical, chemical and in particular mechanical properties of materials. These changes are often long lasting; in many cases thermal treatment seems insufficient to restore original mechanical properties. In relation to the sharp change in physical-mechanical properties of materials subjected to irradiation, one may note two aspects.

1. The changes in physical-mechanical properties, mostly nonuniformly distributed through the volume, require the development of new theories and the perfecting of existing theories and computing methods of instruments which are used to analyze radioactive fluxes.

2. The stability of properties acquired during irradiation introduces the problem of improving the quality of constructional materials by means of irradiation, the development of radiation hardening technology and, simultaneously, the production of technological standards of protection from the harmful effects of irradiation on the properties of the materials.

Although there is a large amount of data on changes in physical-mechanical properties of materials during irradiations, analysis of the data from the two mentioned points of view has almost entirely been neglected.

In the present paper a review of the literature pertaining to this question is given, mainly foreign. Basic attention is given to generalization and classification of actual data pertaining to property changes in materials that apparently will help the specialist in strength and the engineer to become familiar with measurement methods. A cursory description of physical mechanisms of the irradiation phenomenon is given. In the last paragraph several general considerations pertaining to calculations in the plasticity theory of the changes in mechanical properties during irradiation are touched upon. 274 references are given.

From author's summary by Anna M. Turkalo, USA

2462. Lad, R. A., Survey of materials problems resulting from low-pressure and radiation environment in space, NASA TN D-477, 18 pp., Nov. 1960.

On the basis of our present knowledge of the space environment, one might state that the exposure of materials to the radiation environment will present problems mainly with the impairment of the transparency of plastics and ionic solids due to ultraviolet radiation and with surface sputtering effects on emissivity and other thin film properties. The high vacuum in space will be of greater consequence in that it will render useless some members of practically all of the material classes. However, adequate solutions to most problems can be anticipated if enough information is at hand. This survey indicates that information is lacking at levels from the basic to the applied. A partial list of research areas in need of attack is included. From author's summary

Structures: Simple

(See also Revs. 2303, 2334, 2369, 2370, 2378, 2416, 2427, 2456, 2753)

Book—2463. Umanskogo, A. A., Analysis of spatial structures [Raschet prostranstvennykh konstruktsii], Vol. 5, Moscow, Gosudarstvennoe Izdatel'stvo Literatury po Stroitel'stvu, Arkhitekture i Stroitel'nym Materialam, 1959, 555 pp. 29 r. 35 k.

This volume contains 28 papers dealing with various topics in structural mechanics. The first, "Spatial deformation of beams after buckling," by V. V. Bolotin, employs nonlinear theory in conjunction with energy methods to investigate postbuckling behavior of an I-beam subject to combined lateral and axial loads. The second, "Analysis of thin-walled bars subject to bending and compression," by A. A. Pikovskii and A. A. Derkachev, uses linear theory to obtain eigenvalues of critical loads of a cylindrically shaped section subject to axial compression and bending. The next paper, "Some generalizations in the theory of thin-walled bars," by A. A. Derkachev, treats the same problem when the section is subject to bending about its two principal axes, as well as to torsion. The fourth paper, "Stability of compressed bars, loaded eccentrically with respect to each axis," by B. M. Broude, employs linear theory to obtain the eigenvalues of load. The fifth paper, "A more precise solution of the Prandtl-Timoshenko problem," by the same author, considers the title problem (bending of a deep beam) by an energy method, employing nonlinear theory.

The next paper, "An experimental investigation of the stability of compressed steel bars with load applied eccentrically about each of two axes," by G. M. Chubkin, reports tests on about one hundred such bars loaded into the plastic range. Empirical formulas summarize the results. The seventh paper, "Application of a special method to the stability analysis of regular bar systems,"

by V. D. Shaikevich, treats by linear theory a continuous beam on discrete elastic supports. The bar is compressed axially, and all deformations determined. The eighth paper, "Development and generalization of Bubnov's method with application to the free vibrations of stretched or compressed beams on elastic supports," by V. G. Chudnovski, treats the title problem on the basis of linear theory and presents natural frequencies for a wide range of bar and foundation parameters. The ninth paper, "Solution of one stability problem with the aid of a dynamic analog," by B. N. Kutokov, investigates the compression of a beam on discrete elastic supports and determines buckling loads by use of the relation between buckling and free vibrations. The tenth paper, "Spatial stability of arches," by Yu. V. Krotov, investigates spatially curved arches by linear theory and determines elastic buckling loads. The next paper, "Analysis of the latticed system of V. G. Zhukov for strength, rigidity, and stability," investigates a latticed spherical dome subject to normal loading on the basis of linear theory.

The twelfth paper, "Analysis of spatial trusses by the method of models," by T. A. Pokov, reports model tests on pyramid-shaped bar structures subject to static loads. The next paper, "Analysis and construction of supported electrical lines," by E. M. Bucharin, deals with tower systems to support overhead electrical transmission lines. The following paper, "Generalization of Moire's method for determination of elastic displacements," by M. I. Dlugach, investigates beam bending and the Boussinesq problem by the method mentioned. The fifteenth paper, "Analysis of a thick square plate, clamped on two edges," by P. M. Varvak, solves the equations of three-dimensional elasticity by finite difference methods for the title problem. The sixteenth paper, "Application of polynomials to the solution of problems of bending of orthotropic plates," by K. A. Kitover, is based upon the idea of an approximate solution to the linear equation written as a harmonic function in one variable, multiplied by a polynomial in the other variable. The next paper, "Analysis of beam-plate construction," by B. E. Ulitskii, presents a rather elementary analysis of a plate supported by flexible ribs, the usual concepts of effective width being employed. The following paper, "Methods of analysis of circular-ribbed plates," by D. V. Vainberg, employs power series to obtain approximate solutions to problems of radially ribbed plates subject to various normal loadings, such as segmental loads distributed over a number of equally spaced radii.

The next paper, "Spherical shells whose edges are subject to cyclic influences," by Yu. B. L'vin, investigates, on the basis of the linear Vlasov equations, deformations in partial spherical shells subject to edge disturbances of harmonic nature. The twentieth paper, "Analysis of cylindrical shells and reinforcing rings subject to concentrated loads," by A. I. Tyulenev, studies the statics of a long shell reinforced by equally spaced rings, a radial concentrated load being applied to an arbitrary ring. Displacement components are assumed to be represented by Fourier series and the coefficients determined. The next paper, "Stability of cantilever cylindrical shells subject to bending by transverse forces together with torsion and internal pressure," by V. M. Darevskii, presents an elementary linear analysis of the problem, together with reporting results of tests on 33 shells. The following paper, "Stability of reinforced cylindrical shells subject to transverse bending," by K. D. Turkin, offers a linear analysis of a medium length shell subject to different magnitude bending moments at each end, together with equal transverse shears applied at the ends.

The next paper, "Stability of cylindrical shells subject to torsion and internal pressure," by V. A. Mar'in, presents an analysis of the problem on the basis of Donnell's linear equation. Results are presented in a simpler form than previously found by Hopkins and Brown. "Stability of cylindrical panels subject to shear," by the same author, is the topic of the next paper. Nonlinear analysis is employed, and the equations solved by the Galerkin procedure. "Stability of cylindrical shells subject to torsion, external pressure, and compression," is the twenty fifth paper, by O. I. Terebushko. Nonlinear analysis is employed, together with the principle of minimum potential energy. The following paper, "Stability of orthotropic cylindrical shells, loaded by axial forces and external pressure," by O. N. Len'ko, investigates the title problem by the same method. The twenty-seventh paper, "Influence of axial compression on natural frequencies of cylindrical shells," by M. V. Nikulin, investigates frequencies on the basis of the linear Donnell equations solved by assumed harmonic displacements. The last paper, "Free vibrations of shallow shells, reinforced by edge ribs," by A. A. Narzarov and B. N. Bublik, employs minimum energy concepts to solve the title problem.

To summarize, the book is an excellent collection of original papers in the various areas of structural mechanics.

W. A. Nash, USA

2464. Hilton, H. H., and Feigen, M., Minimum weight analysis based on structural reliability, *J. Aerospace Sci.* **27**, 9, 641–652, Sept. 1960.

Fundamental and original contribution to probabilistic design of structures in general. Authors deal with systems in which failure of each element is independent of that of all other elements for any given condition of loading, and failure of any single element brings about failure of the entire structure. In practice such structures are not often met except as much simplified idealization. Assuming that the probability of failure of the system is small, this leads to the conclusion that it is nearly equal to the sum of the probabilities of failure of all individual members. Authors show that, contrary to a common statement, optimum design requires that the various elements in a given system have different allowable probabilities of failure.

General relations are derived between probability of failure and weight of individual members for a variety of conditions of loading. Types of failure considered include buckling, creep, etc.

As an illustration, for mathematical simplicity authors assume Gaussian distribution for a number of parameters and take the corresponding coefficients of variation as constant. (The latter assumption is perhaps more reasonable than the former.) From here they derive a number of design charts and comparative diagrams. It is concluded that, given an over-all probability of failure, the proposed approach effects economies in weight of 2 to 8 per cent, under usual conditions, in comparison with conventional methods using constant factor of safety.

Paper is clear and stimulating and opens new avenues of research.

E. Rosenblueth, Mexico

2465. Plunkett, R., and Gurtin, M. E., Use of excess constraints in structural analysis, *J. Mech. Engng. Sci.* **2**, 2, 101–104, June 1960.

Authors use stiffness matrix to determine force-deflection relationships for an elastic structure. Method utilizes extra constraints in the structure to divide it in parts small enough to make easy calculation of stiffness matrix coefficients. Proper choice of extra constraints enables one to calculate forces (and moments) from unit displacements (and rotations) from well-known relationships. Many of the extra constraints will be zero. Author contributes method to remove excess constraints without inverting the entire stiffness matrix containing unnecessary terms.

Matrix is partitioned into two matrices of lower order, one containing the applied forces, the other containing the excess constraints of zero magnitude. Matrix is then: $f_1 = K_{11}x_1 + K_{12}x_2$ and $f_2 = K_{21}x_1 + K_{22}x_2 = 0$, where the applied forces are in f_1 and the excess constraints in f_2. After substitution of the second equation in the first: $f_1 = (K_{11} - K_{12}K_{22}^{-1}K_{21})x_1$, and $x_2 = -K_{22}^{-1}K_{21}x_1$. Unknown x_1 is then found by matrix inversion of f_1 and used to find x_2.

Advantage of method allows larger matrix to be inverted by digital calculator of given size. Unless desired, the second equation involving unnecessary constraints need not be calculated.

L. M. Laushey, USA

2466. Poppleton, E. D., Note on the design of redundant structures, Univ. Toronto, Inst. Aerophys. TN 36, 22 pp., July 1960.

This note is concerned with the redesign of redundant structures having undesirable stress distributions. A matrix equation is derived relating specified stresses in certain structural members to changes in the stiffness distribution necessary to achieve these stresses. The equation is nonlinear, in general, but can usually be solved quickly by iteration. The method of Argyris and Kelsey is used in the analysis.

From author's summary

2467. Hesse, H., Analysis of circular cross-section reinforced-concrete bars with uniformly distributed reinforcement subject to bending and compression (in German), *Beton u. Stahlbeton.* **55**, 6, 132–134, June 1960.

Using simple elastic equations author obtains maximum stresses in concrete and steel for solid and hollow cylindrical sections under combined axial load and bending moment.

G. G. Meyerhof, Canada

2468. Borodich, M. K., and Kartseva, N. A., The rational geometry of the transverse sections of steel ferroconcrete and steel beams (in Russian), *Uch. Zap. Belorussk. In-ta Inzh. Zh.-d. Transp.* no. 3, 437–450, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10895.

It is stated that the optimum height of a steel beam working in an elastic phase can be represented as a function of the moment of resistance. The optimum height of a steel double-I beam working in a plastic phase can be determined from the condition of minimum weight of one linear meter. Its height is greater than in the elastic phase. The problem is also investigated of the selection of a rational height for a steel ferroconcrete bridge. Approximate relations are given for the selection of a transverse section of a steel ferroconcrete bridge in advance of the assigned delimited structural height.

V. A. Ivanovich

Courtesy Referativnyi Zhurnal, USSR

2469. Akhvlediani, N. V., The future development of methods of calculation of ferroconcrete structures up to destruction (in Russian), Joint Scientific Session of the Building Materials and Construction Institutes of Transcaucasia, Rep. 1957, Baku, 1958, 142–149; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10865.

The question is studied of developing the methods of calculation up to destruction to include redundant ferroconcrete arches and toroid shaped shells. For the arches a method is revived, proposed previously by the author [see *Soobshch. Akad. Nauk GruzSSR* **16**, 10, 793–798, 1955; *Trudi In-ta Stroit dela Akad. Nauk GruzSSR* **6**, 51–58, 1957]. A method is used which converts the lines of pressure into a broken system consisting of two cuttings, which simplifies the calculation. Examinations are made of a two-hinged and of a hingeless arch under the action of a vertical load. For the toroid shell a method is employed which was previously developed by the author for use with cupolas [see *Soobshch. Akad. Nauk GruzSSR* **18**, 2, 205–210, 1957]. A kinematic analysis is advanced of the spatial mechanism in which, in agreement with the experiments on models, the shell behaves in the destruction stage.

K. S. Zavriev

Courtesy Referativnyi Zhurnal, USSR

2470. Topaloff, B., Analysis of reinforced concrete curved beams (in German), *Beton u. Stahlbeton.* **55**, 5, 113–117, May 1960.

Using an approach similar to Winkler-Bach theory, author presents theory and method for analysis of curved, singly-reinforced-concrete beams under pure moment. Tensile stresses in concrete are conventionally neglected. Substantial differences between case in which moment causes tension at the outside and case in which moment causes tension at the inside are disclosed. Charts which would be helpful in design are presented for both cases, taking the concrete in compression and the steel to be elastic with a modulus ratio of 15. Author discusses very briefly case in which concrete is not linearly elastic.

J. E. Goldberg, USA

2471. Ylinen, A., and Eskola, A., Theory of a statically indeterminate pin-jointed framework the material of which does not follow Hooke's law (in English), Sixth Congress, International Association for Bridge and Structural Engineering, June 27–July 1, 1960, 167–176.

General theory of statically indeterminate framework following nonlinear stress-strain relationship is discussed on basis of method of virtual displacements and principle of minimum complementary energy. Illustrative example using simple stress-strain function is given and shows convenient approach.

G. G. Meyerhof, Canada

2472. Cullimore, M. S. G., An application of strain energy to the solution of stiff-jointed structures with many members, *Civ. Engng., Lond.* **55**, 650, 1159–1160, Sept. 1960.

There is nothing new in this paper. The material presented can be found in any good structure book which treats the strain energy method (or least work method) adequately.

K.-H. Chu, USA

2473. Rosenblueth, E., and Holtz, I., Elastic analysis of shear walls in tall buildings, *J. Amer. Concr. Inst.* **31**, 12, 1209–1222, June 1960.

The method of analysis for the determination of the distribution of loads in tall buildings containing a shear wall is presented. It is assumed that the lateral displacement of a frame in any one story is proportional to the shear acting in the frame in that story and that the moments and shears in the girders supported by a shear wall are proportional to the flexural slope of the deflected wall. With this assumption the restrictions offered by the rest of the structure to the shear wall displacement consist of bending moments and shear which are proportional to the wall rotation.

The shear wall can be idealized as a beam on elastic foundations in which the reactions are proportional to the wall rotation rather than to its displacement and can be solved by Newmark's methods of successive approximations. The method requires that a first configuration be assumed and that it be improved by successive approximations. The paper presents two methods for arriving at the first configuration. One method makes use of critical negative stiffnesses while the second method is based on the solution of a differential equation representing the behavior of a building idealized as having uniformly distributed mass and stiffness. An example problem is included.

The author does not claim the solution to be a rigid analysis since many uncertainties exist with regard to the actual stress distribution in the structure. Column shortening, plastic deformation and the effect of foundation rotation have been neglected in this analysis.

G. L. Jeppesen, USA

2474. Penzien, J., Dynamic response of elasto-plastic frames, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 7 (*J. Struct. Div.*), 81–94, July 1960.

This paper presents the results of an analytical investigation involving a single mass system that has an idealized elastoplastic resistance deformation relationship.... All results are presented in the form of graphs showing the maximum dynamic response of the system during the simulated earthquake input plotted against

natural period for various combinations of ultimate strength and damping. From author's summary by E. F. Masur, USA

2475. Martin, L., and Hernandez, J., Orthogonal gridworks loaded normally to their planes, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 1 (*J. Struct. Div.*), 1–12, Jan. 1960.

Numerical example of the slope-deflection-gyration method, where the torsional stiffness as well as the flexure stiffness of the gridwork bars are taken in account.

E. Seydel, Germany

2476. Borodyanskii, M. Ya., The strength of cupolas built up with frames (in Russian), Calculations for large constructions, no. 4, Moscow, Gosstroiizdat, 1958, 73–100; *Ref. Zb. Mekb.* no. 5, 1959, Rev. 5651.

This is an investigation of an elastic cyclically symmetrical beam-cupola open at the pole, consisting of *m* plane closed *n*-angled frame collar beams, rigidly connected at the joints with plane broken meridianal frame-ribs. The load is nodal, acts in the planes of the ribs, identically for all the ribs. The condition for the critical loading is the equality to zero of the determinant of the system of canonical equations for the method of transpositions of the order *4mn*. The procedure is given for its derivation and for expressions for the typical elements. The basic kinematic parameters are represented by *3mn* angles of turn of the nodes and by *mm* tangential displacements of the collar beam's elements. In the corresponding equations of equilibrium account is taken of the deflection and torsion moments which appear as the result of the declination of the transverse forces and the accretion of longitudinal forces corresponding to the last. Special functions are used whose arguments are linked with the parameters of the load through the values of the longitudinal forces. The basic kinematic parameters are linked linearly with the parameters of the group displacements of the cyclic structure; the corresponding conversions of the columns and lines of the determinant result in its taking a quasi-diagonal form with blocks of an order not higher than *4m*. Symbolic methods are proposed for the recording of the given conversions. The author shows that if one accepts the form of divergence of the system from the initial position, it can be assumed but not asserted that the corresponding critical values for the load's parameter actually take part in the spectrum of the critical parameters of the general problem (which was set with no assigned form of divergence), though this is not specially substantiated by the conversion of the determinant to the quasidiagonal form. In the abstractor's view these misgivings in regard to the problem being investigated could have been dissipated earlier had consideration been given to the cyclical character of the form of the free vibrations (ensuring their mutual orthogonality) which holds good for any value for the parameter, the critical among others.

Ya. B. L'vin

Courtesy Referativnyi Zburnal, USSR

2477. Snitko, N. K., The kinematic method in problems dealing with the stability and deformation strength of complex beam structures (in Russian), Investigations in the theory of constructions no. 7, Moscow, Gosstroiizdat, 1957, 209–222; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10737.

The derivation and use of equations is examined, comprised of a hinged system of calculations for frames by employing a method of moments (equations of three or four moments) for their deformation and also by using the method of angular transpositions. Examples of the calculations are given: the determination of the critical load for the simplest type of frame, the calculations for a radio-mast, the computation for the compressed boom of an open bridge.

A. A. Pikovskii

Courtesy Referativnyi Zburnal, USSR

2478. Strel'bitskaya, O. I., Influence of torsion on the magnitude of the limiting load in hingeless frames (in Russian), *Dop. Akad. Nauk URSR* no. 9, 937–942, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10618.

Paper concerns an investigation of the boundary state of a rectangular Π-shaped hingeless frame of double-I and channel-bar thin-walled profile when subjected simultaneously to torsion and bending. The loading consists of forces acting on the crossbar. By using relations previously obtained between the force factors in the boundary state, author is able to develop formulas for the calculations of the maximum deflection moment of the basic system (a frame with one hinged and one roller support) for two boundary cases; (1) when, in the boundary condition, three plastic hinges make their appearance on the crossbar and (2) when, in the boundary condition, one plastic hinge makes its appearance on the crossbar and two plastic hinges at the upper ends of the supports. An example is given for the determination of the boundary value of the distributed load, applied parallel to the plane of the frame on the crossbar with an eccentricity on the concrete frame of double-I thin-walled profile, to meet the case when in the boundary condition there are three plastic hinges on the crossbar. For the case in point an investigation is made to determine the influence of the eccentricity of the applied load on its boundary state. The results of the investigation show a marked fall in the magnitude of the boundary load when there is an increase in the eccentricity when applying the load.

E. A. Raevskaya

Courtesy Referativnyi Zburnal, USSR

2479. Tarasenko, I. I., Computation for the bending of a curved girder the material of which shows irregular resistance to tension and compression (in Russian), Report of the 16th Scientific Conference of the Prof.-Lect. Staff of the Leningrad Engng.-Constr. Institute, Leningrad, 1958, 538–546; *Ref. Zb. Mekb.* no. 5, 1959, Rev. 5665.

The pure bending of a girder of large curvature is investigated on the assumption that the diagrams for the tension and compression of the material are not the same but similar to each other in the sense that one diagram can be produced from the other by a proportional increase of all the ordinates. In addition, the assumptions are made that the stressed state at any point in the girder is mono-axial and that the transverse sections after deformation continue to be plane. The first assumption, when the girder is in the loaded state, is factually identical with the assumption that the moduli of elasticity in tension and in compression are not equal, which does not appear to be sufficiently substantiated for metals customarily used for machine construction. The author obtains expressions determining the location of the neutral line and values for the stresses; it was found that the location of the neutral line depended not only on the form of section and curvature of the girder but also on the direction of the deflection moment. This circumstance forced the author to investigate separately the cases of positive and negative direction of the deflection moment. The paper continues by putting forward formulas for the boundary deflection moment, obtained from an examination of the elasto-plastic stage of loading. The limiting stage is taken to be the stage at which the stresses in the internal fibers of the girder attain the limit of flow, corresponding to a relative residual deformation equal to 0.002.

S. V. Boyarshinov

Courtesy Referativnyi Zburnal, USSR

2480. Rassudov, V. M., An effective method for the solution of the problem of the deformation of a sloping cylindrical arch strengthened by *n* different curvilinear stiffening ribs (in Russian), *Trudī Saratovsk. Avtomob.-Dor. In-ta* **15,** 1, 137–151, 1957; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10519.

A method for solving the problem for the type of arch described in the title is proposed; the arch is rectangular in plane. It is as-

sumed that the neutral axes of the stiffening ribs coincide with the coordinate lines of the middle surface and that the principal axes of inertia of the transverse sections of the ribs are parallel and perpendicular to the middle surface of the arch. The arch is loaded with an even transverse load q, while normal loads Q_i are acting on the stiffening ribs, evenly distributed along their length. The problem leads to the integration of a system of $2n + 2$ equations of equilibrium and joint deformation on the contours of the arch and on each of the stiffening ribs, with corresponding boundary conditions. This solution is reached on the assumption that the rectilinear edges of the arch are freely supported while the curvilinear are identically fastened in arbitrary fashion. The change in length of the neutral axes of the stiffened ribs and of their torsional rigidity is disregarded. By presenting the solution of the system of differential equations in the form

$$w_i = \sum_{k=1}^{\infty} f_{ik}(x) \sin \frac{k\pi y}{b}$$

$$F_i = \sum_{k=1}^{\infty} \varphi_{ik}(x) \sin \frac{k\pi y}{b}$$

(where w_i is the function for the deflection, F_i the stress function) and the resolution of the loads q, Q_i in series by the sines, the initial system of equations is replaced by an infinite system of ordinary differential equations of the eighth order relative to $f_{ik}(x)$. For the determination of the arbitrary constants of the general solution a system of $8n + 8$ algebraical equations is obtained. A method is proposed, enabling calculation difficulties to be reduced, which is linked up with finding these arbitrary constants.

M. S. Kornishin

Courtesy Referativnyi Zhurnal, USSR

2481. Beck, H., Load distribution width for concentrated and line loads for plates supported on two sides (in German), *Bauingenieur* **34**, 3, 94-101, Mar. 1959.

Book—2482. Goodier, J. N., and Hoff, N. J., edited by, Structural Mechanics (Proceedings of the First Symposium on Naval Structural Mechanics, Stanford University, Aug. 11-14, 1958), New York, Pergamon Press, Inc., 1960, xi + 594 pp. $9. (Revs. 2482-2499)

2483. Harwood, J. J., Promisel, N. E., and Maltz, J., Trends in materials to meet the problems of structural mechanics, 20-47.

2484. Sternberg, E., On some recent developments in the linear theory of elasticity, 48-73.

This paper begins with a discussion of the theory of integration of the fundamental equations of linear elasticity theory, with brief mention of the work of Airy, Maxwell, Morera, Beltrami, Finzi, Weber, Galerkin, Papkovitch and Mindlin, inter alia. A discussion of Betti's formula for the dilatation at an interior point of an elastic body under specified surface stresses leads to an investigation of Saint-Venant's principle, and the essential features and outline of proof of the principle as modified by von Mises are given. The concept of a concentrated force is then clarified and problems of three-dimensional stress concentrations considered, mention being made of the work of Goodier, Neuber, Edwards, Robinson, Eshelby, Green, Sneddon, Eubanks, Sternberg, Sadowsky, Gangvetadze, Ling, Miyamoto, Reissner, etc. From work by Green, Ritz and Alblas the conclusions are reached that the stress concentration due to a hole in a plate is nearly independent of the plate-thickness/hole-diameter ratio and that the true average of the stresses acting parallel to the plate faces are adequately predicted by the generalized plane stress solution. Recent trends in elastostatics mentioned here include the two-dimensional work of Green and Stevenson and of Muskhelishvili and his school, work on torsion and flexure by Weber and Günther, the transform techniques of Sneddon and Tranter, and the variational principle discovered by Reissner.

The paper constitutes an important survey of classes of problems with which Professor Sternberg is closely associated. Of particular interest is the section on Saint-Venant's principle and isolated singularities. As in the case of uniqueness theorems, lack of precision here has in the past led to many incorrect or nonphysical solutions. The extensive list of references is most valuable.

R. Tiffen, England

2485. Reissner, E., On some problems in shell theory, 74-114.

Author discusses (a) the formulation of two-dimensional differential equations used for the solution of specific shell problems, and (b) the solution of boundary-value problems in two-dimensional theory. Derivation of shell equations is accomplished in two manners; namely, parametric expansion and variational methods. The paper is limited to the consideration of shallow and circular cylindrical shells.

C. B. Matthews, USA

2486. Fung, Y. C., and Sechler, E. E., Instability of thin elastic shells, 115-168.

Paper explains that little use has been made of the general equations in stability theory which have been based on various orders of approximation using tensor notations. One reason for this lack of use is attributed to the difficulty in solving nonlinear partial differential equations. The wide scatter and nonrepeatability of experimental data afford difficulty for comparison with theoretical results. Paper discusses general equations; the formulation of buckling problems; circular cylinders under external pressure; torsion, or axial compression; spherical shells; and conical shells.

C. B. Matthews, USA

2487. Rivlin, R. S., Some topics in finite elasticity, 169-198.

This is a cartesian account of finite elastic deformation theory as it stands at the present time, excluding questions of stability and the theory of plates and shells. The equations of motion are given and the constitutive equation for materials for which the stress components are single-valued functions of the deformation gradients are deduced. Perfectly elastic material is defined, the existence of a strain energy function proved and the constitutive equations for compressible and incompressible material derived. The effect of symmetry of the material in the undeformed state is considered. Some approximate forms for the strain energy function for isotropic materials are discussed and the important distinction between the case in which the principal extensions and rotations of the volume elements are both small and that in which only the extensions are small is clearly brought out. Forms of the strain energy function used by Voigt, Mooney and Rivlin are discussed. The paper concludes with solutions to problems involving large deformations and the superposition of infinitesimal deformations on such deformations.

This is a concise and interesting account of finite elasticity theory. It is a pity that general tensor analysis is not used, as the latter is the ideal language for this type of investigation.

R. Tiffen, England

2488. Mindlin, R. D., Waves and vibrations in isotropic, elastic plates, 199-232.

This paper provides a useful survey of the subject. The complexity of plate vibration phenomena is mitigated by a gradual approach, the analysis progressing continuously from infinite solid to bounded plate by way of half-space and infinite plate. Each case is treated first with mixed boundary conditions (e.g. a rigid, perfectly smooth support) which introduce no coupling between P

and SV waves: the development of coupling is then traced by considering the gradual reduction of elastic boundary supports. The discussion of the results includes a concise account of recent developments. J. D. Robson, Scotland

2489. Kolsky, H., Experimental wave-propagation in solids, 233–262.

This is an excellent review of the state of the art. The author deals with the different means of producing stress waves and of observing them. Each method is presented clearly and its advantages and limitations are analyzed. The author also deals with some of the results obtained from the experimental study of elastic wave propagation in bars, plates and blocks, and from some experimental studies on viscoelastic, plastic and shock waves. The paper ends with the expression of a hope: "that some of those interested in the field attempt more experimental work and venture away from the Hellenic tradition of inferring the behavior of the world around by the sole use of pure reason." Amen.

A. J. Durelli, USA

2490. Bleich, H. H., Dynamic interaction between structures and fluid, 263–284.

2491. Flax, A. H., Aero and hydro-elasticity, 285–333.

The field of aeroelasticity, particularly in relation to hydroelasticity, is surveyed. Insofar as the fundamentals of the subject are concerned it matters not whether a vehicle is moving in air or water, provided that the effects of the free surface of the water may be neglected. In this sense aeroelasticity and hydroelasticity are the same. Practically, however, because of differences in speed ranges, types of structure, weight limitations in design, and compressibility of the medium, as well as the possibility of cavitation, there are substantial differences between the problems of airborne and waterborne vehicles. This paper is restricted mainly to the aeronautical approach to such problems with applicability of concepts and methods to the problems of ships indicated where possible.

Selected topics are divided into two parts. Under static aeroelasticity are discussed the torsional divergence of a straight wing of high aspect ratio, finite span corrections, general theory for a system of a finite number of degrees of freedom and sweptback wings. Under dynamic aeroelasticity are discussed the general theory of the flutter of continuous structures, the adjoint equations, the aerodynamic forces in flutter, two-dimensional analysis of bending-torsion flutter, panel flutter, flutter analysis of aircraft and transient loadings. Due to lack of space topics such as the influence of thermal stresses, structural and aerodynamic nonlinearities at high supersonic Mach number, viscous effects on the flow, buffeting and self-excited vibrations due to wakes and von Karman vortex streets and the aerodynamic pressure field of jets and propellers have been omitted. Eighty-one references are listed.

A discussion entitled "Hydroelasticity: A New Naval Science" by S. R. Heller, Jr. and H. Norman Abramson presents an interesting comparison between Collar's "aeroelastic triangle" and a counterpart suitable for application to naval architecture. Many topics unique for hydroelasticity are pointed out.

G. C. K. Yeh, USA

2492. Junger, M. C., Structure-borne noise, 334–377.

Paper concerns role of structural elements in transmitting vibratory energy from a source to a fluid medium. The following subjects are among those discussed: stress waves of dilatation, distortion, torsion, and flexure; structural joints in form of T, X, or L; mechanical impedance mismatch caused by changes in cross section, changes in material properties, and addition of inertia elements; coupling between energy source and structural elements; coupling between structure and fluid medium; use of viscoelastic materials for damping; experimental techniques. Paper has 76 references, discussion has 5 more. Paper covers period up to 1958. Reviewer feels author presents an outstanding summary of subject technology. J. C. Burgess, USA

2493. Boley, B. A., Thermal stress, 378–406.

2494. Drucker, D. C., Plasticity, 407–455.

Author extends the criteria of stability to a stable elastic-plastic material. He postulates for all inelastic material that the work done by an external agency on the change in displacements it produces must be positive or zero. The stability postulates are put in appropriate mathematical form. A narrow and an extended postulate of stability of material or of geometry are given for homogeneous state of stress and strain. It is shown that the stress-strain relations, some permissible idealizations, variational and extremum principles, the theorems of limit analysis and design, buckling of structure, shakedown, fracture and dynamic problems are made more understandable by means of these postulates.

The incremental or flow theory is presented. Author proves that the initial yield surface and all subsequent loading surface must be convex and the plastic strain increment vector must be normal to the yield or loading surface and lie between adjacent normals at a corner.

Author has presented an excellent review and reference list for complete solutions and for applications of the preceding theories. Experimental and calculated results and diagrams are shown for a plate designed by the limit theory.

Very interesting is the discussion. The comments of Prof. Zizicas (University of California) and of Prof. L. W. Hu and J. Marin (Pennsylvania State University) are particularly fine.

S. Sarkadi Szabo, Hungary

2495. Lee, E. H., Viscoelastic stress analysis, 456–482.

Linear viscoelastic analysis covering the recent work and significant problems has been surveyed. The relation between forms of representation of viscoelastic behavior and their influence on the methods of attack on stress analysis problems are discussed. Practical tests for viscoelasticity and linearity are suggested.

G. S. Verma, USA

2496. Hetenyi, M., Photoelasticity and photoplasticity, 483–505.

2497. Vigness, I., Instrumentation, analyses, and problems concerning shock and vibration, 506–532.

Author gives general review of methods available for the measurement of strain and motion associated with shock and vibration. The account is biased to practical techniques of use in field testing, and limitations and calibration of equipment are considered. Brief reference is made to high-speed photographic techniques and to limitations on strain gages imposed by hazardous conditions of shock testing, especially high temperatures and high nuclear radiation flux. Author concludes with brief account of analysis of data derived and the application of the analysis in testing and design of equipment. The 24 references include some to Government reports so that wider knowledge of the availability of these reports is made possible.

In the discussion G. J. O'Hara comments on the difficulties of analyzing the effect of shock spectra on dynamic reaction of structures and C. T. Molloy on the use of the four-pole-parameter technique for determining the resultant impedances of a structure.

K. W. Hillier, England

2498. Greenberg, H. J., Solving structural mechanics problems in digital computers, 533–556.

Paper presents a brief critical survey of current use of typical medium and large-size computing systems (IBM-650 and IBM-704). Also includes some case histories of particular computer applications; namely,

(1) Nonlinear deflections of shallow spherical shells;

(2) Nonlinear bending and buckling of circular plates;

(3) Plastic torsion of cylinders.

The final section contains some conclusions and suggestions for future work. C. B. Matthews, USA

2499. Irwin, G. R., Fracture mechanics, 557-594.

The paper presents fracture mechanics, with practical applications, and concludes with a list of suggested topics which require investigation. From author's summary

End of Symposium

Structures: Composite

(See also Revs. 2303, 2386, 2413, 2436, 2438, 2464, 2472, 2473, 2516, 2517, 2537, 2614, 2638)

2500. Haruoka, M., Okabe, T., and Hori, K., An experimental study on model continuous beam bridge with steel deck (in English), *Publ. Int. Assn. Bridge Struct. Engng.* **18**, 137-170, 1958.

Steel orthotropic plates have been recently used with advantage as bridge decks.

Authors analyze a special type of bridge composed of four three-span continuous girders connected by an orthotropic plate, with and without transverse bracing.

Experimental results obtained on a steel model are compared with theoretical ones calculated by various methods, including one developed by authors that also considers influence of shearing forces on deflections.

Effective width to be used in computing rigidity of girders and stiffners is discussed and the convenience of separately considering symmetrical and antisymmetrical loading is emphasized.

It is concluded that usual methods give satisfactory results for computing distribution coefficients at midspan but errors can be considerable at other sections. F. Borges, Portugal

2501. Gunther, H., Stresses and deformations in circular cylindrical shells and application to silo and container construction (in German), *Bautechnik* **37**, 3, 95-98, Mar. 1960.

Known theory of linearly elastic cylindrical shell is applied to compute stresses and deformations in silos constituted of cylindrical walls of constant thickness from foundation to top. Bottom is assumed to be conical, spherical or plane, and far enough from top and foundation so edge effects do not interfere and hypothesis of infinitely long cylinder can be used.

H. Fernandez Long, Argentina

2502. Heller, S. R., Jr., and Palermo, P. M., Methods of elastic analysis of circular bulkhead stiffening systems, David W. Taylor Mod. Basin Rep. 1336, 43 pp., Nov. 1959.

Authors develop a procedure for the structural design of a submarine bulkhead. The bulkhead is essentially a stiffened circular plate, under hydrostatic pressure, both normal to and in plane of the plate. The stiffening consists of a main horizontal beam, secondary vertical beams and a tertiary system of small horizontal beams. As basis of design procedure, exact beam theory solutions, shear deformation included, are developed for six cases of beams under elliptic, constant, and uniformly spaced concentrated loadings. End thrust and end rotational restraint are considered for the uniformly loaded beams. By suitable assumptions on the load distribution and the geometry of the beam systems, these theoretical solutions provide the basis for a design procedure for the stiffeners regarded as beams. The procedure is simplified by the use of nomographs.

Comparisons of the elastic analysis with full-scale experiments on submarine bulkheads are included.

J. E. Duberg, USA

2503. Coleman, T. L., Press, H., and Meadows, May T., An evaluation of effects of flexibility on wing strains in rough air for a large swept-wing airplane by means of experimentally determined frequency-response functions with an assessment of random-process techniques employed, NASA TR R-70, 33 pp., 1960.

See AMR **12**(1959), Rev. 334.

2504. Harlander, L. A., Optimum plate-stiffener arrangement for various types of loading, *J. Ship Res.* **4**, 1, 49-65, June 1960.

Rectangular gross plate panels with stiffeners in one direction are considered under pure uniform hydrostatic load and under pure edge compression parallel to stiffeners respectively. For hydrostatic loading two boundary conditions are investigated: stiffeners with hinged ends with plating clamped, and stiffeners and plating clamped. Under compressive loading stiffeners and plating were assumed to be simply supported.

In case of hydrostatic loading total weight of gross panel is determined as a function of panel dimensions, number of stiffener spaces, hydrostatic head, design stress of stiffeners, and design stress of plating. Derivation with respect to number of stiffeners yields equations for minimum weight. Design curves are given which show that optimum stiffener spacing is quite close and the plating quite thin.

For compressive edge loading parallel to stiffeners curves are given showing various stiffener-plate combinations on a plot of critical load per foot versus stiffener spacing. Lines of constant weight are plotted to allow selection directly of the solution yielding minimum weight. For smaller loads minimum weight is obtained when plating is thin and stiffeners closely spaced. For heavy loads, and thus heavy stiffeners, the stiffener-plate combination of minimum weight is not very sensitive to stiffener spacing due to the low slenderness ratios, in the case treated.

E. R. Steneroth, Sweden

2505. Weiss, H. J., Deflections of an abutment wingwall considered as a thin trapezoidal plate, Iowa State College, Iowa Engng. Exp. Sta. Bull. 185, 11 pp., May 1959.

2506. Ripken, J. F., An experimental study of flexible floating breakwaters, Univ. Minn., St. Anthony Falls Hydraul. Lab. Tech. Pap. 31, Series B (Contract NBy-3143), 72 pp., Oct. 1960.

Machine Elements and Machine Design

(See also Revs. 2369, 2533, 2823)

2507. Dikhtiarv, F. S., Cutter for gear teeth in M. L. Novikov's gearing system (in Russian), *Vestnik Mash.* **39**, 9, 8-13, 1959.

Using a trigonometric approach, equations are derived for the cartesian coordinates of the profile of a cutter designed to produce gear teeth having essentially convex or concave tooth profiles, as used in the Novikov gearing system.

F. Freudenstein, USA

2508. Karnushev, N. S., The bases of the theory of hydraulic braking gear of mine hoisting equipment (in Russian), *Nauchn. Trudi Mosk. Gorn. In-ta* no. 23, 37-59, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10169.

The derivation and solution are given of the differential equations of motion for the hydro-loaded braking gear. Differential equations are also given for a hydro-spring gear, in which braking is performed by means of a preliminarily deformed (compressed or tensioned) spring or a battery of springs, while for the "setting" of the springs, a supplementary hydraulic unit is provided. The analysis made enables the conclusion to be reached that for the investigation of the dynamics of the hydro-spring gear the same relations can be used as were obtained for the hydro-load gear.

B. S. Dorogov

Courtesy Referativnyi Zhurnal, USSR

2509. Rohonyi, W., Approximate calculation of the rigidity of straight bevel gear teeth (in German), *VDI Zeitschrift* **102**, 15, 615–618, May 1960.

The question of whether the tooth-loss factors for spur gears have to be corrected when applied to straight toothed bevel gears can be answered by the distribution law of the line load along the straight bevel gear teeth. The degree of correct longitudinal and vertical convexity is also a function of the line load, or of the elastic deformation of the straight bevel gear tooth. But before a distribution law of the line load can be produced, the rigidity of the bevel gear teeth must be investigated.

From author's summary

2510. Makhonina, T. M., Calculations for pressed-on setting of discs beyond the limit of elasticity (in Russian), Calculations for strength no. 3, Moscow, Mashgiz, 1958, 237–251; *Ref. Zb. Mekh.* no. 9, 1959, Rev. 10608.

An investigation is made of the problem of setting one disk into another with an amount of tension resulting in the appearance of elasto-plastic deformations in one of the disks or in both. The solution of the problem is put through on the basis of the tension diagram without toughening, while using Mises' condition for plasticity. The problem is solved by the introduction of a supplementary variable φ from whose function the required magnitudes of the stresses and transpositions are obtained. The expressions for these magnitudes contain trigonometrical and exponential functions φ which, for simplification of the calculations, are incorporated in a table. An example is given of the calculation of a disk setting with an assigned contact pressure of a magnitude which results in both the disks deforming elastoplastically. The magnitude of the required tension is determined.

N. M. Sapozhnikov

Courtesy Referativnyi Zhurnal, USSR

2511. Bolotin, V. V., Fatigue life of structures subject to quasi-stationary stresses (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **29**, 30–36, 1960.

Author considers the fatigue life of structures subject to varying stresses represented by random, quasi-stationary processes. These processes are defined as near-stationary, whose probability characteristics are slowly varying functions of time compared to the function itself. An example is the stress in aircraft structures subject to atmospheric turbulence or acoustic excitation.

Formulas are derived for determining the cumulative fatigue life of a structure taking into account the history of loading. The fatigue life is expressed in terms of a function G representing the measure of metal conditioning before development of fatigue cracks, and a function D which indicates the measure of failure development itself.

An example is worked out using the derived formulas. It confirms the stated experimental fact that a preliminary conditioning or "training" of a sample at lower stresses initially tends to increase the fatigue life, while the same training at higher than nominal stresses tends to greatly decrease the fatigue life of a specimen.

Reviewer believes the method used is a new and valid approach for the type of problem investigated.

V. Chobotov, USA

2512. Vereshchagin, L. F., Fedorovsky, A. E., Isaikov, V. K., Slesarev, V. N., and Semerchan, A. A., The possibility of using plastic solids as the working medium in hydraulic power cylinders (in Russian), *Inzhener. Fiz. Zh.* **3**, 7, 132–134, July 1960.

It is shown experimentally that it is possible to increase the working pressure in the cylinder of a hydraulic press to 10–15 thousand atmospheres by using a plastic solid body instead of a liquid.

From authors' summary

2513. Rakhmatulin, Kh. A., Theory of formation of fabric (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **27**, 5–16, 1960.

Author investigates the formation in fabrics of a region of incompletely packed woof threads, a so-called "surf zone." By elementary means he deduces formulas for the angle that the warp threads make in passing over the woof threads, the width of the "surf zone," and thread stresses.

E. E. Zajac, USA

Rheology

(See Revs. 2365, 2366, 2368, 2430, 2633)

Hydraulics

(See also Revs. 2312, 2350, 2490, 2506, 2536, 2541, 2544, 2600, 2605, 2660, 2774)

Book—2514. Knapp, F. H., Flow through orifices, over weirs and under gates in hydraulic structures. Applied hydraulics on a physical basis [Ausfluss, Uberfall und Durchfluss im Wasserbau—Eine angewandte Hydraulik auf physikalischer Grundlage], Karlsruhe, Verlag G. Braun, 1960, xxiii + 671 pp. DM 78.

This is a complete treatise of a large part of applied hydraulics, dealing with flow through orifices, nozzles and valves, over free and submerged weirs of different forms, and through variable openings under sluice-gates. Thorough theoretical derivation of formulas for flow is presented. Author considers dynamic pressure distribution caused by curved streamlines and the resulting force effects; these important facts are usually disregarded in computation of weirs and gates. Many recent textbooks of fluid mechanics mention orifices and weirs as devices for flow measurement only. Therefore this book is of great importance for hydraulic designing engineers. It is based on long experience of the author in teaching and conducting planning of power plants in Brazil. A few details could be improved, such as origin of the proportional weir.

It is unusual for the German press to see mispelled names, as Bundschuh for Bundschu, Scimeni for Scimemi, Woycicky for Wóycicki. Also surprising is complete absence of Brazilian literature in references. Reviewer suggests that this unique book should be translated and published in English.

S. Kolupaila, USA

Book—2515. Karaushev, A. V., Problems of dynamics of natural water streams [Problemy dinamiki lestestvennykh vodnykh potokov], Leningrad, Gidrometeorologicheskoi Izdatel'stvo, 1960, 392 pp. $2.80.

Comprehensive treatise on mechanism of river flow, sediment transport, and channel formation covers these topics: turbulence, pulsation, velocity distribution; wind and ice influence; secondary flow; form of water surface, its variations; wind waves, their re-

fraction and diffraction; solutions and heat distribution; lift and shift of sediments; development of natural channels. Many opinions and methods are presented and discussed. A valuable list of references includes 130 Russian titles and 18 foreign (4 English). Book would be of interest for our hydraulic engineers.

S. Kolupaila, USA

2516. Andreiev, O. V., Planning of river crossings [Proiektirovanie mostovykh perekhodov], Moscow, Avtotransizdat, 1960, 295 pp.

This textbook for students of highways is reasonably improved from the first edition of 1949. It contains classification of crossings, characteristics of rivers and valleys, hydrologic procedures in planning crossings, waterway determination in permanent channels, planning of approaches, channel regulation features at bridges, crossings at peculiar circumstances, field investigations for river crossings. Methods of maximum discharge determination, based on methods by Hazen and Foster, are developed by Russian engineers. Percentage of lakes, swamps, and forests is taken into account, and local empirical coefficients are obtained by interpolation on a map. Chapter on bridge planning over wandering and meandering streams is of particular interest, being based on the broad practical experience of the author. Flow in the main channel and across the valley are compared and various solutions discussed. Scour under bridges and around piers is discussed in detail, and measures of control are featured. Book presents a good review of methods applied at present in the USSR. Bibliography mentions the books and papers of Russian authors only.

S. Kolupaila, USA

2517. Watkins, R. D., Steady flow in an open channel with varying cross-sections and bed-slopes, *Instn. Engrs., Australia*, CE 2 (*Civ. Engng. Trans.*), 1, 1–9, Mar. 1960.

Author develops a method of calculation of varied steady-state flow in open channels where either or both the cross section and bed slope vary, by evaluating finite differences. The formulation of the method is presented in general terms and then is illustrated by an analysis of flow in a channel with a number of control structures and with varying cross sections and bed slopes.

In the opinion of the reviewer this paper has merit, presenting to the profession a practical tool for problems of the character outlined. It may also be recommended for study to graduate students because it makes evident the influence of the section and slope on varied flow in open channels by numerical computations. However, the reviewer doubts whether the application of the method requires less numerical operations than that using the Bakhmetev's varied flow function, the tables for which, due to Chertousov, have been available since 1935 for positive slopes and the hydraulic exponents from 3 to 4.0 with intervals of 0.1 and for larger values with larger intervals and due to Ven Te Chow, since 1955, from 2.2 to 7.0 with intervals of 0.2 and also for larger values with larger intervals. For zero and negative slopes tables are also available. The fact that the conveyance function follows sufficiently close the exponential relations, was empirically established by Bakhmetev and published by him in 1912. The author therefore incorrectly states that it "appears to have been publicized" by him in 1932. This relation makes possible the integration of the varied flow equation and the computation of numerical values of varied flow functions mentioned above.

B. S. Browzin, USA

2518. Kuplenskii, A. A., The integration of the differential equations for the curves for the flow and fall (of streams) (in Russian), *Trudi Omskogo S.-kh. In-ta* **26**, 139–152; 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10123.

Author presents the known differential equation for the slowly changing motion of water in prismatically shaped channels in the form of $\partial S/\partial b = f(b)$, where b is the depth of the flow, while the axis S is directed along the flow. For curves having a free surface of the type of a_I, b_I, a_{II}, b_{II} and c_{II}, the function $f(b)$ is replaced by the approximate relation

$$f(b) = \frac{b}{a + bb} + c(s),$$

where a, b, c are constants. A comparison is made between a number of results of the calculations for S by this equation and the results of calculations made by the methods employed by B. A. Bakhmetev, N. N. Pavlovskii and others.

Remarks by the abstractor: The accuracy of the calculations, carried out by the various methods of free surfaces sloping at considerable angles, is incorrectly evaluated by the error in the magnitude of coordinate s at identical depths, instead of by the error in the magnitude of the depth in a given section. The initial relation which has been adopted appears to be wrong inasmuch as the magnitude of the derivative under examination should decrease in conformity with that relation with decrease of the positive values of the depth; actually, for curves for the effluent of type a_1 the derivative increases with decrease of depth, attaining (at a normal depth) infinity.

R. R. Chugaev

Courtesy Referativnyi Zhurnal, USSR

2519. Pritvits, N. A., Hydrodynamic analysis of a circulatory cesspool of continuous action(in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 25–31, May/June 1959.

Paper is an approximate hydrodynamic analysis of the flow in one of two types of cesspools, originally designed by Salakhov in 1945. Author states that satisfactory laboratory performance tests were reported by Potapov in 1947. Author considers circulatory, nonviscous, axially symmetric flow. Solutions for uniform spiral flow with the appropriate boundary conditions are obtained by introducing two different auxiliary stream functions, solving in each case for the velocity distributions, and also reducing to the special case of a potential vortex. Comparison with experiments reveals that the general spiral solution agrees better with observed paraffin sphere paths, i.e. yields more probable radial velocity distribution. Author suggests that improved description of flow could be obtained by considering more rigorously the boundary conditions, viz., the constancy of the free surface pressure, as well as by taking into account the slope of the pool bottom.

T. Ranov, USA

2520. Pavlov, G. G., Determination of backwater wave in a feeding channel during overflow (in Russian), *Gidrotekh. Stroit.* **28**, 4, 43–45, Apr. 1959.

Backwater wave occurs in a derivation canal due to the operation of a power plant. Level rise is maintained in certain limits by installation of side or end weirs or spillways. Graphical method is developed for determination of a flow rate necessary for stabilizing levels. Results of laboratory tests are presented.

S. Kolupaila, USA

2521. Ostrovskii, A. I., The generalization of a method for the construction of curves for the free surface in tubes of circular section (in Russian), Trudi Tashkentsk. In-ta Inzh. Irrig. i Mekhaniz. S. Kh., Gidrotekhn. Sektsiya no. 6(7), 143–145, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10124.

It is proposed to modify the equation and the supplementary calculation tables, previously recommended by the author [see *Gidrotekhn. i Melioratsiya* no. 3, 44–51, 1955], for the construction of curves for the free surface in round tubes by making use of the hydraulic characteristics of the flow when the slope of the bottom is critical. It is stated that the new equation derived in this way holds good for all cases of curves constructed for a free surface in pressureless covered water conduits. An example is given for the

application of the recommended relationships. The example gives no indications of the magnitude of the discharge and the coefficient of roughness, both essentials for the solution of the problem in question. M. E. Faktorovich

Courtesy Referativnyi Zhurnal, USSR

2522. Khachatrian, R. M., Hydraulic design of the bottom grid for a mountain feeder (in Russian), *Gidrotekh. Stroit.* **29**, 12, 29–34, Dec. 1959.

Inadequacy of existing formulas for water discharge through racks is proved and a new formula proposed which accounts for the inclination angle of a bottom grid and for angularity of the stream.

S. Kolupaila, USA

2523. Konopkin, B. K., and Tkachenko, V. A., Discussion of "Hydraulic resistance of deep plane gates of circular section" by I. A. Zababurin (in Russian), *Gidrotekh. Stroit.* **29**, 6, 48–49, June 1959.

Discussers doubt validity of Zababurin's test data and dispute applicability of loss coefficients recommended by him as function of sluice gate opening. Reasons for criticism are: lack of clear definition of head loss symbol, resulting in apparent confusion between over-all coefficient of entire test section and the entrance loss coefficient proper; discrepancy between discussers' and author's (much higher) values for entrance loss coefficient, if based on discussers' interpretation; disagreement between the effects of sill height on the coefficient, etc. In closure, author stands by experimental formula given in original paper, claiming inappropriateness of discussers' comparisons with geometrically dissimilar cases. He emphasizes role of sill height and formation of entrance vortex in producing changes of loss coefficient.

T. Ranov, USA

2524. Silberman, E., and Song, C. S., Instability of ventilated cavities, Univ. Minnesota, St. Anthony Falls Hydr. Lab. Tech. Pap. 29, 45 pp., Nov. 1959.

Experimental evidence indicates that cavities formed by ventilating wakes of moving bodies are of two types—steady and vibrating. Cavitation number σ is reduced by ventilation to a critical value, $\sigma \leq 0.19\, \sigma_v$, below which only vibrating cavities occur.

$$\sigma = (p_0 - p_k)/\frac{1}{2}\rho\, v^2$$

(p_0 = undisturbed pressure, p_k = cavity pressure, ρ = liquid density, v = undisturbed velocity, $\sigma_v = \sigma\, p_k$ = vapor pressure of fluid at temperature).

Curves of σ/σ_v for various air supply rates and foil shapes are provided. J. S. Marcus, USA

2525. Shmuglyakov, L. S., Methods for investigating cavitation in hydraulic machines, based on the physical features of the flow (in Russian), *Trudi Khar'kovsk. Politekhn. In-ta* **17**, 37–45, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10163.

Cavitation leads to changes in the electric properties of a flow, a fact used by the author in evolving a new method for cavitation investigation. The author discards the use of the capacity method which demands the application of currents of very high frequency and sensitive to parasite capacities. A thermo-electrical method in variant form investigated by the author did not give the required accuracy. An Ohmic method is recommended, which is founded on the well-defined relation of the electroconductivity of the flow to the intensity of the cavitation phenomena and to the cavitation coefficient. The strong influence of the air-content of the flow on this coefficient is noted. A brief account is given of the author's studies on cavitation, which were carried out by observation of its noises in the region of high (beyond the limit of audibility) frequencies and by radiation of the flow with ultrasonic vibrations. The actual schematic plans used and the results of these experiments are not given. N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR

Symposium on mechanics of real fluids, Indian Institute of Technology, Kharagpur, India, April 1958; *J. Sci. Engng. Res., India* (Part 2) **3**, July 1959. (Revs. 2526–2530)

2526. Thiruvenkatachar, V. R., Cavitating motion of underwater missiles, 187–198.

2527. Govinda Rao, N. S., Cavitation phenomenon, 199–222.

2528. Chatterjee, P. N., Modern concept of the mechanics of cavitation and cavitation damage, 223–238.

2529. Thomas, K. C., The mechanism of cavitation pitting, 239–262.

2530. Seetharamaiah, K., Water tunnels, 263–278.

End of Symposium

Incompressible Flow

(See also Revs. 2312, 2315, 2317, 2515, 2524, 2564, 2570, 2581, 2595, 2598, 2649, 2660, 2686, 2697, 2775, 2776, 2800, 2825)

2531. Ludwieg, H., Stability of the helical flow in an annulus between two coaxial cylinders (in German), *Z. Flugwiss.* **8**, 5, 135–140, May 1960.

Author investigates the stability of nonviscous helical flow in annulus between coaxial cylinders. Criterion for stability against helical vortices of the Taylor type is derived from Rayleigh's criterion. It appears that a radial gradient of the axial flow component is a destabilizing factor.

L. J. F. Broer, Holland

2532. Rusanov, B. V., The stationary plane linearized problem of the hydrodynamics of a viscous incompressible liquid with large Reynolds numbers (in Russian), *Nauchn. Doklad' Vyssh. Shkoly, Fiz.-Matem. Nauk* no. 1, 68–70, 1958; *Ref. Zh. Mekh.* **9**, 1959, Rev. 10174.

The stationary plane problem is solved of the flow about a profile by a viscous incompressible liquid at large Reynolds numbers. A method of linearization is proposed which appears to be an extension of ideas advanced by Oseen. The velocity vector and the full pressure are presented in the form

$$u = u_0 + v', \qquad q = q_0 + q' \qquad (q_0 = p_0 + \tfrac{1}{2}\rho u_0^2 = \text{const})$$

Here u_0 is the velocity of the potential flow about a body by an ideal liquid, while v' and q' are the magnitudes being sought. The expressions for u and q are substituted in the Navier-Stokes equations. After setting aside the terms $v_k' \, \partial v_i'/\partial x_k$, a linear system is obtained and solved. An arbitrary contour, the exterior of which is mapped conformaly on the exterior of a unit circle, is investigated. Fredholm's equations for vortices are solved for large Reynolds numbers. Asymptotic values for velocity and pressure are given for large Reynolds numbers. A similar method of linearization, as an extension of ideas advanced by Oseen, was originally proposed in a general form in 1926 by Tseilon [*see* C. W. Oseen, Hydrodynamik, supplement]. V. B. Minostsev

Courtesy Referativnyi Zhurnal, USSR

2533. Ponomarev, I. N., On the leakage of fuel in the packing clearances of a plunger couple of a fuel pump of an internal combustion motor (in Russian), *Sb. Nauchn. Tr. Tomskii Elektromekban. In-ta Inzb. Zb. D. Transp.* **22**, 136–150, 1956; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10164.

Some questions regarding the leakage of fuel through the pistonring clearance of a simple plunger couple are investigated. The theoretical investigation proceeds on the assumption that when the fuel reaches the clearances a type of laminar flow of the liquid is developed with a Pouiselle profile for the distribution of velocities. An empirical relation is obtained for the viscosity of the fuel to the pressure. Formulas are derived for the calculation of the leakages in plain plunger couples, with account being taken of the deformation of the walls of the packing surfaces and also of the changes in viscosity of the fuel due to pressure. The presence of elastic deformations is explained as being due to the jamming of the plunger in the sleeve when the pump is working. It is shown that when calculating the fuel losses due to leakage the elastic deformations in plunger and sleeve cannot be disregarded. The author holds the view that the results of his present study could find application in the manufacture of different types of plungers.

Yu. A. Lashkov
Courtesy Referativnyi Zburnal, USSR

2534. Rozenbaum, R. B., and Todes, O. M., The theoretical analysis of the constrained fall of a sphere into a viscous liquid (in Russian), *Zap. Leningrad Gorn. In-ta* **36**, 3, 16–27, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10182.

By use of the theory of similarity the authors obtain, in a general form, the correlation between the magnitudes determining the steady fall of a heavy sphere into a vertical cylindrical tube filled with a viscous liquid. Use is made of the equations of hydrodynamics, the boundary conditions and the supplementary conditions of equilibrium between the vertical component of the total hydrodynamic pressure on the surface of the sphere and its weight. It is demonstrated that the composition of the determining factors of dimensionless parameters can be studied by the criteria attributable to Reynolds and Archimedeus

$$A = \frac{gd^3}{\nu^2}\frac{\delta - q}{q}$$

(δ and q are the densities, respectively, of the sphere and the liquid) and the relation of the diameters of the sphere and the tube d/D. By using simple concepts regarding the flow in the circular clearance between the walls of the tube and the sphere the authors derive a correlation for the region of viscous flow having the form of

$$R \sim \left(1 - \frac{d}{D}\right)^2 \varphi_1\left(\frac{d}{D}\right) A$$

For the quadratic region this becomes

$$R \sim \left(1 - \frac{d}{D}\right) \varphi_2\left(\frac{d}{D}\right)\sqrt{A}$$

A single interpolational form for the relation $R = f(A)$ is proposed for the unhampered fall, comparable with measurements over the whole range of known experimental data.

B. A. Fidman
Courtesy Referativnyi Zburnal, USSR

2535. Gints, B. K., A weighing method for the measurement of the velocities of an airflow (in Russian), *Sb. Nauchn. Rabot. Belorussk. Politekhn. In-ta* no. 69, 5–15, 1958; *Ref. Zh. Mekb.* no. 9, 1959, Rev. 10419.

The so-called weighing method for measuring small velocities of airflow is described. The method is used as follows: the flow of air being investigated is caused to enter a tank containing water for a determined period of time and displaces part of the water from the tank. The weight of the displaced water permits calculations to be made for the volumetric consumption and the mean velocity of the air. Results of the measurements are given, with a mean velocity for the air of 0.5 to 2.5 m/sec.

Yu. V. Abramovich
Courtesy Referativnyi Zburnal, USSR

2536. Dergarabedian, P., The behavior of vortex motion in an emptying container, Proc. Heat Transf. Fluid Mech. Inst., Stanford, Calif., June 15–17, 1960; Stanford Univ., 1960, 47–61 pp.

Author deduces that the surface on the axis of a rotating fluid emptying from a tank depresses as $-\exp(t)$ for specific initial conditions. Radial and axial velocity components are assumed, as is also the form of the solution to the equation of angular momentum. The latter assumption essentially dictates the conclusion reached. Reviewer feels that close agreement between the analysis and an experiment would be mostly fortuitous because of the number of assumptions and approximations made.

The results are used to suggest modeling parameters for vessels of different size but this is not developed in detail. Equivalent results could have been obtained by dimensional analysis.

The surface depression in the steady-state "emptying" of a tank was studied by Einstein and Li [AMR **6**(1953), Rev. 174; **9**(1956), Rev. 2553] but to reviewer's knowledge the author's transient problem has not been previously considered.

R. L. Curl, USA

2537. Miller, D. R., Critical flow velocities for collapse of reactor parallel-plate fuel assemblies, *ASME Trans.* **82** A (*J. Engng. Power*), 2, 83–95, Apr. 1960.

Author treats flat and curved plates, uniform in dimensions and uniformly spaced, and makes the usual simplifying assumptions as to their material properties. The plates are of small thickness compared to breadth, and of small breadth compared to length. They are free of unidentified deformations. The supports are rigid. Author assumes coolant to be incompressible, and precludes leakage.

Bernoulli's theorem is applied to determine pressure differences across plates due to fluid velocity changes resulting from plate deflections. These are then used to derive theoretical expressions for the critical flow velocities at which collapse occurs. The following cases are investigated: (a) Flat plates with built-in edges; (b) flat plates with simply-supported edges; (c) flat plates with longitudinally spaced supports; (d) curved plates with fixed edges; (e) curved plates with hinged edges. The effects of unbalanced channel pressures and of membrane compressive stresses are then examined. Author concludes paper by discussing the validity of the assumptions and derivation of formulas.

Paper is followed by discussions contributed by Irwin Beretsky and E. B. Johansson. Mr. Beretsky submits correction factors to allow for initial local deviations in passage areas, but author, in reply, disagrees with his results. Mr. Johansson analyzes effect on critical velocity due to flow redistribution as result of local deflection of plates, and makes comparisons with author's results.

D. Abir, Israel

2538. Dolapchiev, B., and Sendov, B., Symmetrical flow around a circular cylinder with two vortices behind it. Trajectories of the vortices and drag of the cylinder, *Soviet Phys.-Doklady* **4**, 5, 962–965, Mar./Apr. 1960. (Translation of *Dokladi Akad, Nauk SSSR* (*N.S.*) **128**, 1, 53–56, Sept./Oct. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper considers plane, incompressible inviscid flow around circular cylinder with two vortices symmetrically situated with respect to cylinder and free-stream direction. A simple formula is

obtained for vortex trajectories. For given values of cylinder radius, free-stream velocity and circulation there is one stable vortex position (as shown by Töppl, 1913), and it now appears how trajectories in neighborhood of this position are closed, while others extend to, or come in from, upstream or downstream infinity.

S. B. Berndt, Sweden

2539. Straub, L. G., Bowers, C. E., and Pilch, M., Resistance to flow in two types of concrete pipe, Univ. Minn., St. Anthony Falls Hydraul. Lab. Tech. Pap. 22, Series B, 148 pp., Dec. 1960.

2540. Mendik, I., Economical dimensioning of main pipes in given terminal pressures (in Hungarian), *Energia es Atomtechnika* **13**, 10/11, 459–462, Oct. 1960.

2541. Ito, H., Pressure losses in smooth pipe bends, *ASME Trans.* **82** D (*J. Basic Engng.*) 1, 131–143, Mar. 1960.

The results of extensive experimental studies to determine the pressure losses for turbulent flow in smooth pipe bends of circular cross section are presented in this paper. To make the data usable in practical design problems, the results are discussed in relation to those found by previous investigators, and empirical formulas for the bend-loss coefficient are given. The general correlation of the test data appears to be as good as our present test information will permit.

From author's summary

2542. Rozenbaum, R. B., Experimental investigation of the constrained motion of a sphere along the axis of a cylindrical tube (in Russian), *Zap. Leningrad Gorn. In-ta* **36**, 14, 28–37, 1958; *Ref. Zb. Mekh.* no. 9, 1959, Rev. 10183.

Measurements were made of the velocity of fall of spheres in vertical cylindrical brass tubes filled with a viscous liquid. The passage of the spheres through the control sections was recorded with the aid of electrodynamic transmitters and by means of geiger counters which registered the radioactive radiation of the cobalt covering of the spheres. The characteristic parameters showed the following variations: the Reynolds numbers R from 10^{-3} to 10^{-4}, the Archimedean number

$$A = (gd^3/\nu^2)\,(\delta - q)/q,$$

where δ and q are the densities of the spheres and the liquid respectively, from 0.4 to 10^8, and the relation of the diameters of the sphere and of the tube d/D from 0.099 to 0.889. Empirical expressions were obtained for the functions $\varphi_1(d/D)$ and $\varphi_2(d/D)$ which take part in the formulas for constrained fall with linear and quadratic resistance; these were proposed previously on the basis of the theory of similarity. A unit interpolational formula is also selected for the whole range of magnitudes being measured and nomograms are drawn which simplify the calculations for the velocity of the constrained fall. The conditions are investigated at which the constrained fall proceeds at maximum velocity; the corresponding critical values for d/D, obtained from the proposed correlations for two systems of flowing about the sphere, agree with the results of the measurements.

B. A. Fridman
Courtesy Referativnyi Zhurnal, USSR

2543. Borishanskii, V. M., Resistance to the motion of air through a layer of spheres (in Russian), Questions relating to the aerodynamics and heat transfer in boiler-furnace processes, Moskva-Leningrad, Gosenergoizdat, 1958, 290–298; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10374.

Resistances are investigated which are produced by the motion of air through a layer of spheres, in relation to their interspaces, the mutual distribution of the spheres and the height of the layer being blown through. Experiments were carried out to throw more light on the influence exercised by these factors. Air was blown in different ways through spheres in various formations; the spheres were hollow, made of gypsum and porcelain with diameters of 16.5 and 15.6 mm respectively, and also of anthracite fractions 7 to 12 mm. The results of the experiments are shown in graphs. The experiments confirmed the fact that with one and the same interspace density the resistance of the layer may vary considerably with different ways of packing the spheres inside the layer.

M. V. Filinov
Courtesy Referativnyi Zhurnal, USSR

2544. Abraham, G., Jet diffusion in liquid of greater density, *Proc. Amer. Soc. Civ. Engrs.* **86**, HY6 (*J. Hydr. Div.*), 1–13, June 1960.

Effects are studied of buoyancy and velocity on the diffusion of an upward traveling vertical jet into a fluid of greater density (range 2 to 5% denser). The local Froude number F of the jet determines the extent of the influence of buoyancy which increases with decreasing F. Previous work is reviewed and equations given for the two extremes of $F = 0$ and $F =$ infinity, and an intermediate case where momentum is dominant near the nozzle and buoyancy at greater distances.

Experiments are described in which a vertical jet of water is injected upwards into salt solution. Density and velocity of the diffusing jet were measured. Density changes in the jet are in close agreement with theory. Velocity measurements, which are not reported, were considered inaccurate because of lack of equilibrium conditions in the model tank and difficulties experienced in use of pitot tubes.

Reviewer considers that reasons for not measuring velocity are inadequate, but paper increases confidence in using theoretical equations of density change. Although work is intended solely for sewage disposal, equations concerned can be used for dispersal of waste gases from stacks into low turbulence air.

D. B. Leason, England

2545. Franklin, R. E., and Foxwell, J. H., Pressure fluctuations near a cold, small-scale air jet (measurement of space correlations), Aero. Res. Counc. Lond. Rep. Mem. 3162, 17 pp., 1960.

This report gives details of experimental observations on a 2-in. model jet. The observations consist of velocity distributions, root-mean-square pressure fluctuations in the field round the jet and space correlations of the fluctuating pressures in limited regions near to the jet. It is considered that the main interest lies in the space correlations, which were observed by using fine-bore probe microphones and associated correlation equipment.

From authors' summary

2546. Yen, K. T., Study of fluid mixing and related aerodynamic problems, AFOSR TR 60-136 (Rensselaer Polytech. Inst., Dept. Aero. Engng. TR AE 6006), 10 pp., Sept. 1960.

2547. Birkhoff, G., and Fisher, J., Do vortex sheets roll up? (in English), *R.C. Circ. Mat., Palermo* **8**, 1, 77–90, Jan./Apr. 1959.

Authors advance several pieces of evidence which suggest that, in an inviscid and incompressible fluid, vortex sheets do not roll up into point concentrations of vorticity. On the contrary, mathematical arguments (which this reviewer does not claim the competence to judge) are advanced in favor of a tendency toward randomization of the positions of a discrete set of vortices, approximating initially to a vortex sheet. Numerical work on a digital computer supports the authors' view that the system does not evolve (roll-up) in the manner found earlier by Rosenhead [*Proc. Roy. Soc.* (*A*) **134**, 170–192, 1931]; rather a more irregular evolution is found. As the authors rightly point out "the implications of the preceding results .... for thin vortex sheets in real fluids of low viscosity can only be surmised." Even so, the results reported in the present paper are of considerable interest.

J. T. Stuart, England

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 2315, 2330, 2564, 2568, 2582, 2583, 2584, 2599, 2607, 2616, 2617, 2621, 2623, 2660, 2727, 2728, 2732, 2739, 2778)

2548. Munch, J., Supersonic flow around an oscillating body of revolution (in German), *ZAMM* **40**, 7/8, 328–333, July/Aug. 1960.

A source-sink method, suitable for electronic computers, is given for computing the pressure on axisymmetric bodies of revolution that oscillate with an arbitrary frequency in a supersonic flow.

From author's summary by K. G. Guderley, USA

2549. Li, T., Partial derivatives of the von Karman-Tsien potential (in German), *ZAMM* **40**, 7/8, 370–372, July/Aug. 1960.

von Kármán (1932) derived the axial stream function for a body of revolution moving at supersonic speed and Tsien (1938) the corresponding formula for transversal flow, both as integral expressions. Both functions can be presented as special cases of the Riemann integral $\varphi_n(x,r)$ containing Chebyshev's polynomial of the first kind and the *n*th degree. The author derives expressions for the derivatives of the functions $\varphi_{n=2}$, φ_{n-1}, φ_n, φ_{n+1}, and φ_{n+2} with respect to x and r. These expressions can be used for solving boundary-value problems when it is a question of flow against a body of revolution.

E. Niskanen, Finland

2550. Chushkin, P. I., Supersonic flows around blunted bodies of simple shape, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24**, 5, 927–930, 1960. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N. Y.)

The method of characteristics for supersonic flows with curved shock waves is put into a form especially economical of computing time with digital machines. Flow fields for a series of spherically blunted cones and cylindrically blunted wedges at zero angle of attack are computed, starting with supersonic initial data obtained from the second approximation in the integral method of O. M. Belotserkovskii [*Prikl. Mat. Mekh.* **22**, no. 2, 1958; **24**, no. 3, 1960]. Shock shapes, pressure distributions, and wave-drag coefficients are given in graphical form.

Occasionally coalescing Mach waves are interpreted as always due to a physically meaningful recompression and a second shock, rather than as a possible indication of inaccuracy or inconsistency of the data on the initial line (as has been the experience with the method of Gravalos, Edelfelt, and Emmons, 9th Annual Congress, Inter. Astronaut. Federation, Amsterdam, August 1958). No information is given on the over-all relative reflection of the pressure waves from the shock wave and from the sliplines, and the interpretation of the inflection point on the shock wave is superficial. Otherwise, the results are consistent with the classifications and interpretations of S. Traugott ["Some features of supersonic and hypersonic flow about blunted cones;" Tenth Inter. Congress of Applied Mech., Stresa, Italy, Sept. 1960].

M. V. Morkovin, USA

2551. Nocilla, S., Design of two-dimensional nozzles for supersonic wind tunnels (in Italian), *Aerotecnica* **39**, 5, 232–238, Nov. 1959.

A general method for design of two-dimensional nozzles for supersonic wind tunnels is presented. Three problems are to be solved: (a) Perfect fluid flow from nozzle upstream section to throat; (b) supersonic flow from throat to test section; (c) corrections for boundary layer. Hodographic procedure is used to obtain a stream function satisfying equations set by Tomotika and Tamada [Parts I, III, *Quart. Appl. Math.* **7**, p. 381, 1950; **8**, p. 129, 1951; AMR **3**(1950), Rev. 1982; **4**(1951), Rev. 3936]. This function must provide a suitable axial velocity distribution and reproduce inversion of isovels curvature from intake to throat. Method is applied to design of three different types of nozzles and their rates of flow.

A. Balloffet, USA

2552. Wu, J. H. T., An experimental study of perforated intake diffusers at a Mach number of 2.50, Univ. Toronto, Inst. Aerophys. Rep. 69, 29 pp. + figs., Sept. 1960.

A two-dimensional and an axisymmetric diffuser with perforations on the convergent portion were tested at a free-stream Mach number of 2.50. Schlieren photographs have shown that contrary to the simplifying assumption of a single normal shock, a prominent lambda shock appears in the convergent portion and multiple shocks occur in the divergent portion. High-speed motion pictures have shown that both shock systems oscillate. No total pressure losses were detected between the intake lip and the multiple shocks downstream of the throat but the over-all total pressure losses were much higher than those based on the normal shock theory. The wall static pressures were the same as those measured along the diffuser axis providing the shock is swallowed and coincided with the pressure distribution of an isentropic flow except in the vicinity of the throat. A long throat did not reduce the total pressure losses. The most effective location of the perforations was found to be in a region just upstream of the throat.

From author's summary

2553. Bloom, M. H., and Steiger, M. H., Inviscid flow with nonequilibrium molecular dissociation for pressure distributions encountered in hypersonic flight, *J. Aerospace Sci.* **27**, 11, 821–835, 840, Nov. 1960.

One-dimensional inviscid nonequilibrium flows of a two-component model gas are studied for prescribed pressure variations and an average reaction rate based on recent data for oxygen recombinations. These flows are interpreted in relation to the flow along streamlines around blunt hypersonic bodies. Assuming equilibrium conditions in the subsonic region it is estimated that the flow in the initial supersonic expansion region, which is approximately of Prandtl-Meyer character, will be chemically frozen with respect to the molecular dissociation of the primary components under the hypersonic, high-altitude flight conditions considered (15,000 to 25,000 ft/sec at 154,000 to 246,000-foot altitude).

From authors' summary by R. A. Gross, USA

2554. Gross, G. L., Hypersonic flow past blunt bodies at small angles of attack, OSR TN 60–1195 (Mass. Inst. Technol., Fluid Dynamics Res. Lab. Rep. 60-4), 52 pp. + charts, Oct. 1960.

An analytical solution is derived for the flow in the nose region of blunt bodies of revolution with conic section profiles, traveling at hypersonic velocities and zero or small angles of attack. The approach chosen is that of linearization of the inviscid equations of motion in the angle of attack and the ratio of the density before to that behind the strong bow shock according to the modified Newtonian approximation. The density is assumed constant for the flow between shock and body surface. The possibility is discussed of a numerical extension into the neighborhood of Freeman's singularity, which does, however, not occur within finite distance from the axis for a paraboloid nose shape.

From author's summary

2555. Towle, W. J., A bimolecular diatomic gas model applied to nonequilibrium blunt-body flow, Mass. Inst. Technol., Nav. Supersonic Lab. Tech. Rep. 462, 71 pp., Aug. 1960.

Derivation of the thermodynamic relations is presented for a bimolecular diatomic gas mixture from statistical thermodynamic considerations including vibrational and dissociational modes. A review and derivation of the reaction rate equation for the dis-

sociational process is given. An approach to the solution of the flow field about a blunt body in hypersonic flow for the nonequilibrium dissociating gas is considered in detail.

From author's summary

2556. Kleiman, Ya. Z., Certain peculiarities in the motion of mixtures, *Soviet Phys.-Acoustics* 5, 2, 158–166, Nov. 1959. (Translation of *Akust. Zh., USSR* 5, 2, 157–165, Apr./June 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Compression and rarefaction waves in a many-component medium are considered in the acoustic approximation. It is shown that behind the wave front, division of the components can occur as a consequence of the difference in their velocities. The features of wave motions of mixtures are explained by a comparison with the analogous motions of one-component media. In particular, the possibility of the origination in a mixture (in specific cases) of a set of waves propagating one behind the other is established, where the number of these waves is equal to the number of components. The first waves are similar to the waves (compression and rarefaction) in a one-component medium; the later ones, however, are characteristic of mixtures, and as the contents of all the components except one tend toward zero (i.e., with the transition to a one-component medium), these waves vanish.

From author's summary by J. W. Miles, USA

2557. Yablonskii, V. S., and Kaganov, S. A., The Couette flow when taking into account the relation of viscosity to temperature and heat generated by friction (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Neft'i Gas* no. 5, 57–65, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10176.

On the assumption that the local coefficient of viscosity depends on the temperature on the principle that $\mu = \mu_0 \exp(-st)$, authors find a solution for a system of differential equations for the flow of a viscous liquid between two parallel plates one of which is moving in relation to the other with a certain constant velocity

$$\frac{d}{dy}\left(\mu\frac{du}{dy}\right) = 0, \quad \frac{\mu}{E}\left(\frac{du}{dy}\right)^2 = -\lambda\frac{d^2T}{dy^2}$$

The solution for the velocity distribution is of the form

$$u = \frac{2c_1c_3}{\mu_0 a}[c_4 - tb[(c_3 - y)c_2]]$$

The temperature distribution is given as

$$T = \frac{1}{s}\log_e\left\{\frac{2c_1^2}{a}scb^2[(c_3 - y)c_2]\right\}$$

Four arbitrary constants entering the solution are determined from the boundary kinematic and thermal conditions. An analysis of the solution follows with different boundary conditions being taken into consideration. Special solutions found previously by other authors are discussed.

V. D. Sokolov

Courtesy Referativnyi Zhurnal, USSR

2558. Chuan, R. L., Research on rarefied gasdynamics, AFOSR 22 (Univ. So. Calif. School Engng. Tech. Rep. 56–101), 115 pp., Nov. 1960.

A research program on rarefied gasdynamics has been in progress at the USCEC since 1956. This is a summary of the activities and accomplishments for the period 1 May 1956 to 30 September 1960. Under the experimental aspect of the program a low-density wind tunnel using a two-phase cycle has been developed, as well as a number of associated pressure and density instrumentation devices. Theoretical efforts in solutions of the Boltzmann equation, and development of associated boundary conditions, and investigations in magnetohydrodynamics (with special emphasis on the motion of artificial satellites) have also been undertaken, and results are summarized.

From author's summary

2559. Pack, D. C., The hodograph method applied to flow past profiles and in jets, AFOSR TR 60-61 (Roy. Coll. Sci. Technol., Glasgow, Dept. Math.), 53 pp., Apr. 1960.

The solution of the Tricomi equation is found for subsonic and sonic flows past thin wedges in an infinite stream or a wind-tunnel with parallel walls, for certain flow models. Drag coefficients have been calculated and hence the effect of the presence of walls has been assessed. A problem, analogous to the Riabouchinsky problem for incompressible fluids, has been formulated and solved for the Tricomi equation.

The Chaplygin equation has been solved for "simple wedge flows." A numerical comparison of the drag for a thin wedge in a jet has been made for the exact (Chaplygin) equation and for the Tricomi and the Tomotika and Tamada approximations.

It is proved that for simple flows past wedges involving sonic jets the physical changes due to the presence of solid boundaries in the flow are completed within a finite distance in those directions in which sonic jet flow prevails. This generalizes a result first enunciated by Guderley for the so-called "critical jet."

Germain's inversion theorem is used to find the solution of the Roshko problem for the generalized hodograph equation.

From author's summary

2560. Garland, D. B., Studies of ground effect on an inwardly inclined annular jet: Part 1, Apparatus and method of testing; effects of aspect ratio and pressure ratio, Univ. Toronto, Inst. Aerophys. TN 37, 18 pp. + figs., Aug. 1960.

A systematic but not exhaustive series of tests was carried out with a 60° inwardly inclined annular nozzle over a wide range of nozzle aspect ratios ($67 \leq AR \leq 524$), pressure ratios (up to 3.0), with and without the presence of simulated ground. Total thrust force was measured and converted to augmentation ratio, using the ideal thrust of an equivalent circular nozzle in free-air as a basis. Nozzle angle of attack was held at zero degrees. Base pressure distributions and nozzle mass flows were also measured but will be published later.

Agreement between test results and available theory is only moderate. A very sudden jet-focusing phenomenon was observed at high nozzle aspect ratios ($AR > 250$) as well as a very pronounced hysteresis effect in the focusing-unfocusing region.

From author's summary

2561. Rozenberg, G. Sh., The measurement of momentary values of the velocity of an unsteady flow of gases when carrying out investigations on gas turbines (in Russian), *Trudi Tsentr. N.-i. In-ta Morsk. Flota* no. 20, 49–57, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10418.

A description is given of a composite tube of the Pitot-Prandtl type for the measurement of the velocity of a gas flow by means of the difference between a full p and a static p_s of the pressures, in the case of an unsteady motion; this is done with the aid of capacity gauges let into the tube in the corresponding portions of the pipe conduits. In order to measure the velocities of gases with p and p_s known a requirement is to have available a Mach number filling the conditions $M < 1$ and $M > 1$; this involves a simultaneous measurement of the temperature T. For this purpose the method evolved by Ya. M. Feenberg and I. S. Kudryatsev [In: Investigation of the working processes in Diesel engines, Moscow-Leningrad, Mashgiz, 1954, 37–56] is used. The method in question consists of the use of a resistance thermometer with a Wolfram filament 15–20 μ in diameter, at a time when thermal inertia is virtually absent when taking measurements in internal combustion engines; the apparatus records the momentary thermodynamic temperature T. When finding substantiation for the use of the ap-

paratus due consideration is given to the natural frequency of the vibrations of the atmospheric column in the tube and the natural frequency of the vibrations of the membrane of the capacity gauges; the resistance to the propagation of pressure waves in the ducts of the probe is also taken into account. Data are furnished in regard to the calibration of the apparatus and for the determination of velocities in the exhaust gas pipe of a motor of type GFR on the basis of measurements of p, p_0, T, recorded by means of the transmitter of a magneto-electric oscillograph.

S. G. Popov
Courtesy Referativnyi Zhurnal, USSR

2562. Friedman, A., Mildly nonlinear parabolic equations with application to flow of gases through porous media (in English), *Arch. Rational Mech. Anal.* **5**, 3, 238–248, 1960.

Author presents a mathematical proof of the existence and uniqueness of a solution for a class of nonlinear parabolic partial differential equations. The equation describing the flow of gases through porous materials is treated as a special case. Conditions are established for the existence of such a unique solution. This is a mathematical treatment and does not include engineering applications. A familiarity with the techniques of mathematical analysis is necessary to understand the development in detail.

G. G. Wallick, USA

Boundary Layer

(See also Revs. 2546, 2555, 2618, 2647, 2649, 2654, 2655, 2761)

2563. Coppel, W. A., On a differential equation of boundary-layer theory, *Phil. Trans. Roy. Soc. Lond. (A)* **253**, 1023, 101–136, Sept. 1960.

The equation involved is the well-known Falkner-Skan equation. The paper is an interesting application of the qualitative theory of differential equations. Weyl's results on the existence and properties of solutions are obtained in a simpler manner, and new results including sharper bounds on the velocity gradient at the wall are found.

While the methods employed do not give the numerical answers needed in engineering applications, the extension to the more complicated systems of boundary-layer equations now under consideration would be of interest to those engaged in numerical computations.

W. Squire, USA

2564. Scholz, N., Extension of the boundary-layer calculation method of E. Truckenbrodt (in German), *Ing.-Arch.* **29**, 2, 82–92, Apr. 1960.

Author presents an extension to the Walz-Truckenbrodt quadrature method for calculating the distribution of the momentum thickness in turbulent boundary layers with impressed pressure gradients. A reconsideration of the form parameter specification to be used in the quadrature to yield the momentum thickness showed a slightly better agreement with experiment. The cases where the fluid properties varied were also considered by introducing a reference temperature in the manner of Rubesin and, later, Eckert. (This same extension to Truckenbrodt's method was outlined by Hartnett, Irvine and Eichhorn in an unpublished paper for the General Electric Co. in April 1956).

Author treats both hydraulically smooth and rough surfaces. He calculates anew the relationship between Truckenbrodt's form parameter L and the boundary-layer thickness ratios H and $\overline{H}$. The results are presented tabularly, in a calculation method arrangement, for (1) laminar or turbulent boundary layer; (2) plane or axisymmetric systems; (3) hydraulically rough or smooth walls; (4) properties dependent or independent of the temperature.

R. M. Drake, Jr., USA

2565. Walker, G. K., A particular solution to the turbulent-boundary-layer equations, *J. Aerospace Sci.* **27**, 9, 715–716 (Readers' Forum), Sept. 1960.

2566. Culick, F. E. C., The compressible turbulent boundary layer with surface mass transfer, AFOSR TN 60-1094 (Mass. Inst. Technol., Nav. Supersonic Lab. Tech. Rep. 454), 64 pp., Aug. 1960.

An approximate analysis of the compressible turbulent boundary layer on a porous flat plate with distributed surface mass transfer is based on a representation comprising two regions. A large portion of the development is quite general, but only the cases of helium and air injection are computed explicitly. The results are restricted to conditions under which the Prandtl and Schmidt numbers may be regarded as functions of concentration alone. Wall concentration of helium and the reduction in skin friction can be calculated from a modified integral method; heat transfer and recovery temperatures are obtained from the differential energy equation. There seems to be acceptable agreement with measurements, with the exception of optimistic recovery factors and a failure to show observed dependence of skin friction on Mach number. An approximate calculation indicates that if the effects of thermal diffusion are accounted for, the first error may be decreased, with but small change in the calculated heat transfer rate.

From author's summary

2567. Velte, W., An application of the Nirenberg maximum principle for parabolic differential equations in the boundary layer theory (in German), *Arch. Rational Mech. Anal.* **5**, 5, 420–431, July 1960.

According to K. Nickel [*Arch. Rational Mech. Anal.* **2**, 1–31, 1958; AMR **12**(1959), Rev. 3492], general considerations concerning the solution of the boundary-layer equations can be made even without their explicit integration. This theory, based on a theorem by Nagumo-Westphal, can be applied only to two-dimensional motions. Using a maximum principle for parabolic equations given by Nirenberg [*Comm. Pure Appl. Math.* **6**, 167–177, 1953], author extends Nickel's results to three-dimensional motions. These new qualitative results are of interest for those who investigate the boundary-layer mathematical theory.

D. Gh. Ionescu, Roumania

2568. Freeman, N. C., and Lam, S. H., On the limiting structure of the edge of a hypersonic boundary layer with very cold free streams, AFOSR TN 59-690 (Princeton Univ., Dept. Aero. Engng. Rep. 468), 23 pp., May 1959.

The structure of the edge of a hypersonic boundary layer in the limit of zero free-stream temperature is analyzed with conventional boundary-layer approximations for a gas with arbitrary Prandtl number Pr and viscosity law $\mu \alpha T^S$. For certain combination of Pr and S the velocity profile has a discontinuity in slope at the edge of the boundary layer. The boundary layer thickness in this limit is always finite for $S > -1$. For $S < -1$ no limiting solution exists for any Pr.

From authors' summary by S. I. Pai, USA

2569. Dorrance, W. H., Dissociation effects upon compressible turbulent boundary layer skin friction and heat transfer, Convair Sci. Res. Lab., San Diego, Calif., Rep. no. 6, 38 pp., Apr. 1960.

The equations for skin friction and heat transfer associated with a dissociating, compressible, turbulent boundary layer are derived from the appropriate boundary-layer equations, making a minimum number of assumptions. The equations of momentum, energy, conservation of mass and species and state are briefly derived taking proper account of terms contributed by turbulent fluctuations. A sublayer-turbulent-layer model is assumed in order to obtain the heat-transfer coefficient to skin-friction coefficient ratio for Lewis number not equal to one. The considerations under which dis-

sociation equilibrium concentrations apply, on one hand, or diffusion-controlled concentrations apply, on the other hand, are examined and it is shown that the use of diffusion-controlled concentrations are quite appropriate for calculating skin-friction coefficient for most cases of interest. The diffusion-controlled concentration profile is then used in combination with the energy and state equations and the Kármán momentum integral to obtain skin-friction coefficients for a flat plate. Prandtl number and Lewis number are assumed equal to one in this latter calculation only. It is shown that the skin-friction coefficients obtained are in excellent agreement with recent measurements by Coles [AMR **8** (1955), Rev. 733] and Matting et al [AMR **12**(1959), Rev. 5661]. Agreement with the heat-transfer measurements of Rose, Probstein and Adams [AMR **12**(1959), Rev. 4101] with dissociation present is also shown. Curves of local skin-friction coefficient are presented for local Mach numbers from zero to four and degrees of dissociation at the surface or in the external stream of from zero to complete dissociation. The equations for calculating local heat-transfer rates are given.

From author's summary by A. Ritter, USA

2570. Coleman, W. S., A theoretical approach to the aerodynamically significant properties of roughness from insects, *Aero. Quart.* **11**, 2, 171–194, May 1960.

In author's previous work [AMR **13**(1960), Rev. 2991] attention is drawn to the difficulties of measuring the streamwise extent of the roughness from insects. The present paper deals with the problem theoretically for an airfoil in two-dimensional, incompressible flow. A tentative approach to the determination of effective excrescence height downstream of the leading-edge zone is also advanced. The application of these investigations, in conjunction with the analysis from author's earlier work regarding the critical conditions for premature transition, leads to estimates of the amount of significant roughness which are in good agreement with flight observation.

From author's summary by R. J. Hakkinen, USA

2571. Sterrett, J. R., and Emery, J. C., Extension of boundary-layer-separation criteria to a Mach number of 6.5 by utilizing flat plates with forward-facing steps, NASA TN D-618, 52 pp., Dec. 1960.

An experimental investigation has been made of the separation phenomena on a flat plate to which forward-facing steps were attached to force separation. Both laminar and turbulent flows were investigated over a Mach number range of approximately 4 to 6.5. The pressure rise at separation, the laminar plateau pressure, and the turbulent peak pressure were determined. The effect of Reynolds number, for the lower Mach number range, and a step height on peak pressure for turbulent boundary layers on plates with forward-facing steps was investigated.

From authors' summary

2572. Landis, F., Fink, M. R., and Rosenberg, M. H., Boundary-layer transition measurements at Mach numbers from 5.4 to 7.4, *J. Aerospace Sci.* **27**, 9, 719–720 (Readers' Forum), Sept. 1960.

2573. Moran, J. P., Application of Covert's approximations for the binary boundary-layer to a porous cone with a solid tip, AFOSR TN 60-834 (Mass. Inst. Technol., Nav. Supersonic Lab. Tech. Rep. 442), 81 pp., June 1960.

Covert's approximations to the solutions to the laminar binary boundary-layer equations as derived by Baron are critically analyzed for the case of helium injected into an air boundary layer. The assumed constant similarity integrals employed by Covert are evaluated for a helium air boundary layer by use of the exact wedge-flow solutions of Baron and Scott.

These approximate relations are applied to the problem of a porous cone having a solid tip. The porous region is of such a composition that an injection distribution of the form $k/\sqrt{x_c}$ exists when both inside and outside walls are at constant pressures. The solutions show that the approximations to the shear and concentration equations give reasonable results, but that the approximations to the energy equation do not. A comparison between these results and correct solutions obtained by a finite difference formulation are presented in another report.

From authors' summary

2574. Moran, J. P., and Scott, P. B., A mass transfer finite difference formulation employing Crocco variables, AFOSR TN 60-846 (Mass. Inst. Technol., Nav. Supersonic Lab. Tech. Rep. 443), 81 pp., June 1960.

Solutions to the laminar boundary-layer equations have been obtained by Flügge-Lotz and Baxter using a finite difference formulation. The same difference approximations are used here to develop a formulation for the binary boundary-layer equations for the case of helium injection into an air steram.

This formulation is used in obtaining solutions to the problem of a porous cone having a solid tip, the porous region having an injection function of the form $k/\sqrt{x_c}$. Corresponding solutions obtained by Moran using Covert's approximations to the equations are compared with the finite difference solutions.

For low levels of injection Covert's approximations to the concentration and shear equations show good agreement with the finite difference solutions.

From authors' summary

Turbulence

(See also Revs. 2569, 2570, 2661, 2761, 2763, 2784, 2797, 2798, 2799, 2801, 2802, 2803, 2805, 2808, 2809, 2810)

2575. Ohji, M., On the theory of homogeneous axisymmetric turbulence, Part 3, *Rep. Res. Inst. Appl. Mech.* **7**, 28, 259–278, 1959.

A careful mathematical analysis of the large-scale structure and final period of decay of axisymmetric homogeneous turbulence is based on the ideas of Batchelor and Proudman [*Phil. Trans. Roy. Soc. Lond.* (*A*) **248**, 949, 369–409; AMR **9**(1956), Rev. 3699]. This analysis indicates that a model of Chandrasekhar [*Proc. Roy. Soc. Lond.* (*A*) **203**, 358–364, 1950; AMR **4**(1951), Rev. 1272] should be modified.

G. Birkhoff, USA

2576. Deissler, R. G., and Perlmutter, M., Analysis of the flow and energy separation in a turbulent vortex, *Inter. J. Heat Mass Transfer* **1**, 2/3, 173–191, Aug. 1960.

Authors study problem equivalent to flow into porous-walled semi-infinite cylindrical cup with solid bottom. Radial and tangential velocities depend only on radius. Axial velocity is independent of radius in central core and in surrounding annulus, and is proportional to distance from bottom. Viscosity is replaced by eddy viscosity and assumed constant, and no-slip condition is relaxed at walls in order to approximate turbulent flow. Radial distributions of tangential velocity and static pressure are computed from compressible equations of continuity and momentum with fraction of mass flow in core and Reynolds number based on inflow velocity at wall as parameters. Energy equation is integrated in linearized form valid not too far from bottom, with heat-condition term modified to measure temperature gradient not from zero but from adiabatic gradient computed from linearized radial momentum equation. Compressibility is found to be essential for energy separation, which is computed and interpreted as primarily due to work done by fluid near axis on fluid farther out by means of shear-

ing stresses. This work vanishes in solid body region because stresses are zero, and in irrotational region because stresses though finite have no resultant torque. Hence energy separation occurs at knee of radial velocity profile, with hot region outside and cold region inside.

Reviewer questions one statement by authors, that heat conduction at wall in idealized problem is essentially different from heat conduction at wall in any real problem. D. Coles, USA

2577. Hama, F. R., and Burke, E. R., On the rolling-up of a vortex sheet, AFOSR TN 60-1069 (Inst. Fluid Dynam. Appl. Math., Univ. Maryland, TN BN-220), 22 pp. + charts, Sept. 1960.

Validity of the classical result obtained by Rosenhead on the rolling-up of a vortex sheet is examined. His computation is found to be doubtful and does not actually result in the rolling up of the vortex sheet in a simple way. First, smaller time intervals must be used for the step-by-step integration of the nonlinear development of the vortex sheet. Second, redistribution of the vorticity along the sheet, as it undergoes a sine-wave distortion, has to be taken into account. It is then shown that the vortex sheet rolls up in a more regular manner. Strong concentration of the vorticity, however, does not result. Effect of positive or negative background vorticity on the rolling-up formation is also considered.

From authors' summary

2578. el Baroudi, M. Y., Measurement of two-point correlations of velocity near a circular cylinder shedding a Karman vortex street, AFOSR TN 60-835 (Univ. Toronto, Inst. Aerophys. TN 31), 7 pp. + charts, Jan. 1960.

Results of an experimental investigation of two-point correlations of velocity near a circular cylinder shedding a Karman vortex street are presented. The measurements were made along a line parallel to the generator of the cylinder which is at 90° from the upstream direction. The cylinder was mounted transversely in an airstream, and two hot-wire probes were used as anemometers.

The curves of correlation coefficient versus probe separation approach zero as the separation between the probes is increased to large values.

A plot of correlation length versus Reynolds number, based in part on a conservative extrapolation, is also presented and compared with correlation length data from pressure measurements taken from earlier investigators.

From author's summary

2579. Soo, S. L., and Tien, C. L., Effect of the wall on two-phase turbulent motion, *ASME Trans.* **82** E (*J. Appl. Mech.*), 1, 5-15, Mar. 1960.

Stationary solution on the effect of a wall on two-phase (solid particles in gas) turbulent motion shows that the intensity of motion of solid particles is affected by the presence of the wall and the distribution of turbulent intensity of the stream near the wall. The intensity of motion of solid particles can be significantly higher than the turbulence intensity of the mean stream. These modifications are consequences of Bernoulli force acting between the wall and the particle. From authors' summary

Reviewer has reservations about the quantitative correctness of the results in this paper. The reasons for these reservations are given in reviewer's discussion of this paper in *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, p. 756, Dec. 1960.

J. L. Lumley, USA

2580. Matting, F. W., Chapman, D. R., Nyholm, J. R., and Thomas, A. G., Turbulent skin friction at high Mach numbers and Reynolds numbers in air and helium, NASA TR R-82, 85 pp., 1960.

Results are given of local skin-friction measurements in turbulent boundary layers over an equivalent air Mach number range from 0.2 to 9.9 and an over-all Reynolds number variation of 2×10^6 to 100×10^6. Direct force measurements were made by means of a floating element. Flows were two-dimensional over a smooth flat surface with essentially zero pressure gradient and with adiabatic conditions at the wall. Air and helium were used as working fluids. An equivalence parameter for comparing boundary layers in different working fluids is derived and the experimental verification of the parameter is demonstrated. Experimental results are compared with the results obtained by several methods of calculating skin friction in the turbulent boundary layer.

From authors' summary

Aerodynamics

(See also Revs. 2330, 2348, 2546, 2548, 2550, 2553, 2570, 2625, 2733, 2751, 2756, 2767)

2581. Pivko, S., A simplified method for estimating the properties of thin aerofoils influenced by jet, *J. Roy. Aero. Soc.* **64**, 593, 292-294 (Tech. Notes), May 1960.

A semiempirical method is given for computing the lift and pitching moment of a two-dimensional airfoil at zero incidence, under the influence of a jet (blowing tangential to the airfoil surface or from its trailing edge), the velocity of which decays to the free-stream velocity in a finite distance. The empiricism lies in determining the effective vorticity in the jet and its effective length from experimental results. Once these are determined, the method of Glauert from classical thin airfoil theory is used to determine lift and pitching moment. Agreement of the latter with experimental results of Dimmock is good.

J. E. McCune, USA

2582. Revell, J. D., Second-order theory for unsteady supersonic flow past slender, pointed bodies of revolution, *J. Aerospace Sci.* **27**, 10, 730-740, Oct. 1960.

An analysis is made of the second-order effects of thickness on the unsteady aerodynamic forces on a slender pointed body of revolution in supersonic flow. The theory is restricted to harmonic oscillations for small angles of attack. The solution is obtained by approximating the nonlinear terms in the second-order potential equation by their first-order values and solving the resulting inhomogeneous partial differential equation, subject to more refined boundary conditions. The pressure equation is likewise refined and integrated to give the second-order corrections to lift and pitching moment coefficients. The analysis can be considered as an extension of the second-order slender body theory of Lighthill to the case of unsteady flow.

The results indicate appreciable reductions in unsteady lift and damping moment coefficients when applied to slender cones. The present theory is estimated to be reliable provided that $M\theta$ is less than 0.7. From author's summary by L. N. Tao, USA

2583. Fenain, M., Theoretical study of supersonic wedge-shaped air-intakes of finite span (in French), *Rech. Aéro.* no. 76, 5-16, May/June 1960.

The air-intake is a finite thin wedge. In the first case, two equal isosceles triangular end-plates are mounted with their apexes at the wedge vertex and their planes normal to the plane of symmetry of the wedge. However, they may be inclined at a small angle to the free-stream direction. In the second case there are no end-plates.

The aim is to find the effect of the finite extent of the wedge on the mass-flow and the drag. The problem is treated by linearized theory of supersonic flow and effect of ends is found from conical flow theory in usual manner. Curves of mass flow versus wedge

angle given for case of no end-plates at two Mach numbers agree well with experimental values.

H. C. Levey, Australia

2584. Carafoli, E., Theory of triangular planes or cross wings in supersonic flow (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **27**, 17-28, 1960.

The goal of the author's work is to establish the foundations of the theory of triangular airfoils and cross-wings in the supersonic flow. As usual in such cases, the author distinguishes two kinds of problems: direct, in which the wing is given and one has to find the distribution of the velocity on it; inverse, in which one has to find the properties of the wing when the velocity pattern is given. The paper begins with list of notions used in the work: polar and Cartesian coordinates, Busemann transformation, etc. The author operates in the complex variable plane, and at first attacks the direct problem for a flat plate wing. The velocity component is represented in form of a series; the boundary conditions, superimposed upon the system in question, refer to the gradient of the velocity potential in the vertical (z)-direction for $z = 0$: the normal velocity component must be equal to zero at $z = 0$. The use of the Euler formula enables the author to solve the problem in a closed form expression for the velocity components. The second problem, that of a cross-wing, is attacked in a similar way with a similar result. The results are presented in a general form, and at the end of the paper the author applies the derived formulas to a particular form. References are made to works in English [M. A. Heaslet, M. Lomax in Vol. VI of Princeton Series; G. N. Lance, *Aero. Quart.* **5**, 1, 1954; AMR **8**(1955), Rev. 1729]; in German [K. Dorfner, Dreidimensionale Ueberschall-probleme der Gasdynamik, Springer-Verlag, Vol. 3, Ergbn. d. Ang. Math., 1957] and the works of the author such as his book ["High Speed Aerodynamics," Editura Tehnica, Bucharest, 1956; AMR **10**(1957), Rev. 2995].

M. Z. v. Krzywoblocki, USA

2585. Swenson, B. L., Exploratory study of the reduction in friction drag due to streamwise injection of helium, NASA TN D-342, 29 pp., Jan. 1961.

A study has been made of the effect on skin friction of the streamwise injection of a light-gas film into a boundary layer. A simple analysis of the flow was made based on the assumption that the boundary layer was completely replaced with this light-gas film. From the analysis, reductions in skin friction of up to about 60 per cent for laminar flows and equal or greater reductions for turbulent flows were indicated with helium used as the light gas. To test this concept, experiments were conducted with a 6° half-angle cone at Mach numbers from 3 to 5 and free-stream Reynolds number (based on cone length) of nominally 1.8 to 10 million. Reductions in the skin-friction drag of about 60 per cent were measured at Mach number 5 with an injection of helium at a mass rate equal to about 0.2 per cent of the mass rate of free-stream air swept out by the base of the model.

From author's summary

2586. Sadoff, M., McFadden, N. M., and Heinle, D. R., A study of longitudinal control problems at low and negative damping and stability with emphasis on effects of motion cues, NASA TN D-348, 53 pp., Jan. 1961.

An investigation was conducted in several types of simulators, including the Johnsville centrifuge, and in flight to assess the effects of incomplete or spurious motion cues on pilot opinion and task performance over a wide range of longitudinal short-period dynamics. Most of the tests were conducted with a conventional center stick; however, a brief evaluation in the centrifuge of a pencil-type side-arm controller was also made.

From authors' summary

2587. Grunwald, K. J., Investigation of longitudinal and lateral stability characteristics of a six-propeller deflected-slipstream VTOL model with boundary-layer control including effects of ground proximity, NASA TN D-445, 98 pp., Jan. 1961.

An investigation of the longitudinal and lateral stability and control and performance characteristics of a six-propeller deflected-slipstream vertical-take-off-and-landing (VTOL) model in the transition speed range was conducted in the 17-foot test section of the Langley 300-MPH 7- by 10-foot tunnel. A complete analysis of the data was not conducted. A modest amount of blowing boundary-layer control was necessary to achieve transition without wing stall.

From author's summary

2588. Neely, R. H., and Griner, R. F., Summary and analysis of horizontal-tail contribution to longitudinal stability of sweptwing airplanes at low speeds, NASA TR R-49, 87 pp., 1959.

Air-flow characteristics behind wings and wing-body combinations are described and are related to the downwash at specific tail locations for unseparated and separated flow conditions. The effects of various parameters and control devices on the air-flow characteristics and tail contribution are analyzed and demonstrated. An attempt has been made to summarize certain data in a form useful for design. The experimental data were obtained mostly at Reynolds numbers greater than 4×10^6 and at Mach numbers less than 0.25.

From authors' summary

2589. Schott, R. L., and Hamer, H. A., Flight investigation of some effects of a vane-controlled gust-alleviation system on the wing and tail loads of a transport airplane, NASA TN D-643, 32 pp., Jan. 1961.

Results are given of an analysis of structural loads measured on a light transport airplane which was modified by the installation of a gust-alleviation control system designed primarily to reduce airplane longitudinal response to turbulent air and thus to improve passenger comfort. Several different gust-alleviation configurations were investigated and the effects of each system on the normal acceleration and loads of the airplane were determined.

From authors' summary

Vibration and Wave Motion in Fluids

(See also Revs. 2520, 2524, 2547, 2651, 2729, 2762, 2763, 2785, 2786)

2590. Jolas, P., The passage of waves over a bar (in French), *Houille Blanche* **15**, 2, 148-152, Mar./Apr. 1960.

Experimental values of reflection and transmission coefficients of low waves passing over a low bar are measured and show agreement with linearized theory. Experimental method of separating direct and reflected waves is by use of three wave gauges on each side of bar. Author calls attention to production by nonlinear effects of shorter-period waves when amplitude of incident longer-period waves is great.

C. Cox, USA

2591. Brill, K. F., Calculation of pressure surges in hydraulic press installations; Part I: Fundamentals; Part II: Check calculations of the measured pressure surges (in German), *Konstruktion* **12**, 2, 60-69, 1960; **12**, 3, 120-130, 1960.

Whenever, in a hydraulic system, the liquid column is accelerated or decelerated, pressure fluctuations are initiated thereby, the maximum and minimum values of which may be significantly higher and lower than the values corresponding to steady flow, and have to be taken into consideration in the design and operation of

the system. With the increasing use of hydraulic control and actuation in machine tools, especially hydraulic presses, the understanding of these phenomena, and their quantitative determination, assumes increasing importance. This subject is treated in present investigation, both theoretically and applied to the actual case of a hydraulic forging press. In Part I the basic principles are explained, and the subject is treated mathematically, based on the classic work of Allievi and Joukowski, as further developed for engineering uses by Schnyder and Bergeron. The graphical method of determining the pressures and velocities as functions of time and of location in the pipeline is explained, with several examples showing the influence of sudden, and of gradual, opening and closing of the flow-control valve. Author also treats the case in which the flow is influenced by an air chamber, or a large water container, included in the pipeline.

In Part II the graphical method is applied to an actual 250-ton hydraulic forging press, the layout of which is shown, and which was fitted with pressure recorders, valve-lift recorder, and other instruments at several locations of the pressure system. Several cases were experimentally and graphically investigated, in particular: (A) Sudden closure of the inlet valve during downward movement of the plunger, whereby on the plunger side of the pipe a cavitation surge, and on the reservoir side of the pipe a pressure surge, is initiated; (B) Stoppage of plunger by its impact on the anvil (resp. on the forging die, or in the experimental case on a lead block) while the inlet valve is open. The experiments were made at several flow velocities, and with several valve opening and closing times. The graphically determined histories of pressure show good agreement with the experimentally measured values. Author concludes that the graphical method is fully reliable and adequate for engineering design and operating purposes, and presents some suggestions for lumping together pipe resistances, and other simplifications, whereby the graphical constructions can be facilitated. K. J. DeJuhasz, USA

2592. d'Hieres, G. C., Study of clapotis (in French), *Houille Blanche* **15**, 2, 153-163, Mar./Apr. 1960.

A theoretical treatment of *clapotis* (standing surface waves of finite amplitude) is carried through to the third order in wave slopes. Equations are based on the Lagrangian plan and incorporate an assumption that the trajectories are closed. Results are explicitly calculated to the third order for finite amplitude correction to wavelength and pressure in water of any depth. The slope of breaking *clapotis* is also calculated and compared with experiment. Agreement is good for great relative depth of water but becomes less satisfactory for shallow. C. Cox, USA

2593. Charles, G. E., and Mason, S. G., The coalescence of liquid drops with flat liquid/liquid interfaces, *J. Colloid Sci.* **15**, 3, 236-267, June 1960.

A drop of liquid of Phase 1, falling through a lighter liquid of Phase 2 onto the Phase 1/Phase 2 interface, rests at the interface for a time before coalescing with the underlying phase. This time of rest follows roughly a Gaussian distribution between a maximum and a minimum value. Results obtained with oil/water system corroborate earlier findings; e.g., stability increases with decreasing temperature and increasing drop size; the time was markedly reduced when the drop contained small amounts of diffusing component, when an electrostatic field was applied, or when the interface was contaminated with solid particles. High-speed cinephotographs of the Phase 2 film between the drop and the interface showed that rupture does not always occur at the same position in the film, and occasionally can occur at two places simultaneously. Expansion of the "hole" was rapid and decreased with time. Results from film rupture studies suggest that rupture of Phase 2 film occurs over a range of thicknesses. Experimental data were mathematically analyzed using equations derived for drop deformation, film thinning, and film rupture. Limits of validity of these equations are discussed. The extensive literature is critically evaluated. K. J. DeJuhasz, USA

2594. Charles, G. E., and Mason, S. G., The mechanism of partial coalescence of liquid drops at liquid/liquid interfaces, *J. Colloid Sci.* **15**, 2, 105-122, Apr. 1960.

Paper reviews former researches of Rayleigh, Weber, Haenlein, Tomotika, and others on the stability of long liquid cylinders and their breakup into droplets. Author investigates, experimentally, the related phenomenon, the case when a drop of liquid of Phase 1, immersed in an immiscible, less dense liquid of Phase 2, falls gently on the flat interface separating Phases 1 and 2, and coalesces with the underlying phase after elapse of a rest time. The coalescence is not complete: the primary drop is followed by a smaller secondary drop of Phase 1, and then the process may be repeated, thus originating a number of successive droplets of decreasing sizes. This mechanism may account for the polydispersity in the coalescence of emulsions and mists. The process of formation of the secondary drop is investigated experimentally by high-speed cinephotography (Fastax 16-mm camera, at film speeds from 1000 to 3500 frames per sec.); several sequences are shown. Diameter ratio of secondary and primary drop varied with the viscosity ratio, and was at maximum at ratio = 1. At very low (0.02) and very large (11) values of the ratio no secondary drops formed. Secondary drop formation could be suppressed by adding a high concentration of surfactant, or by applying an electrostatic field. The experimental results were in reasonable agreement with the Rayleigh theory of unstable liquid filaments.
K. J. DeJuhasz, USA

2595. Borisova, E. P., Koriavov, P. P., and Moiseev, N. N., Plane and axially symmetrical automodel (similarity) problems of stream impact, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 2, 490-507, 1959. (Pergamon Press, Inc., 122 E. 55th St., New York 22, N.Y.)

The problem is related to water entry of wedges and cones. It has been generalized to include other cases where the velocity is proportional to a given power of time. This embraces also the idealized cases of entry into coaxial conical regions and of cumulative explosion of a missile in a conical envelope. Coordinates parallel and normal to the conical surface are used. The numerical solutions obtained hinge on an assumed free surface shape which is quite simple in form and satisfies reasonable kinematic and dynamic conditions. The results for wedges are compared with known solutions and are satisfactory for the range of deadrise angle 20° to 90°, while all the solutions require further improvement for the range of lower deadrise angles. Calculated results for water entry of cones and cumulative explosions are also given. W.-H. Chu, USA

Fluid Machinery

(See also Revs. 2525, 2537, 2818, 2826)

2596. Pumps and compressors (annual survey) (in German), *ZVDI* **102**, 22, 1073-1082, Aug. 1960.

2597. Rehbach, J., Investigation of clearance losses in unshrouded turbine guide vanes with moving hub walls (in German), *Forsch. Geb. Ing.-Wes.* **26**, 2, 58-61, 1960; **26**, 3, 83-94, 1960.

Detailed experimental investigations are imparted of the field of flow in unshrouded turbine guide vanes at various clearances and various speeds of rotation of the hub wall. Readings are taken of the pressure distribution on the blade outline along the blade

height, and also the velocities of flow, the flow angles and the local losses over the entire exit plane of the guide vane. It is apparent that with the usual clearances and speeds of rotation the effect of the rotary motion of the hub wall on the secondary losses is rather small. It would therefore appear permissible to transfer secondary loss readings of cascades with fixed clearance walls to the actual turbine flow. Further, the results of measurement give an interesting insight into the mechanism of clearance flow.

N. K. H. Scholz, Germany

2598. Zhang, H. M., A simple method for designing small high-speed propeller-type water turbine (in Chinese), *Acta Mech. Sinica* 3, 1, 37–44, Jan. 1959.

Paper describes a method of designing hydraulic turbines suitable for rural electrification and other small-scale power generation (output less than 40 kw; specific speed greater than 500 in metric units). The method is based on well-known hydrodynamic principles with emphasis on simplicity and low cost. First step of design is to estimate various head losses in entrance and exit ducts, and equivalent drag of runner. From these, hydraulic efficiency of the turbine is calculated. Runner design is based on blade-element theory using two-dimensional cascade data. Zero incidence and constant pitch are used. The latter is said to simplify foundry procedure for casting the runner. To avoid cavitation, the only specification is that the pressure be positive everywhere on the blade surface. Blade section, thickness, and chord length are determined from considerations of available material, blade loading, and cavitation.

An example is worked out in which tip diameter = 180 mm, hub diameter = 60 mm, axial velocity = 4.5 m/sec, volumetric flow = 0.102 m^3/sec, working head = 1.2 m, and speed = 1050 rpm. It is calculated that efficiency = 50% and output = 600 watts. Runner has 4 blades with NACA-64 series blade sections. No guide vanes are used. This turbine was actually built and tested. Measured results agree very closely with design values.

The work reported in this paper was done under the direction of H. S. Tsien, who is well known in the United States.

T. C. Tsu, USA

2599. Rechkoblit, A. Ya., The extent of the reaction in variable regimes of working of turbine stages with falls in temperature in excess of the critical (in Russian), *Uch. Zap. Leningrad Vyssh. Inzh. Morsk. Uch-shcha* no. 12, 69–82, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 9987.

An investigation is made of turbine stages when large falls of temperature occur, among them those which result in the relative velocity of the flow onto the working blades at the inlet becoming supersonic. For these stages, working at large degrees of expansion of δ, use is made of a divergent valve. The question is examined of the extent of the reaction r on the mean diameter of the combined blade-valve assembly for one-link and two-link stages and also of the necessary conditions for the production of supersonic velocity at the inlet and outlet valves, emanating from one or other of the rims. A joint solution for the equations of continuity and energy gives an expression for the function $r(u/c_0)$ with an assigned magnitude for δ and an assigned part of the turbine between the inlet and outlet valves for the stage, that is the constructional angles and heights for the valves and working blades. In subcritical regimes in the angle β_2 is taken to be invariable and equal to the constructional angle of the working blades β_{2m}; in hypercritical regimes, the declination of the jet in an oblique section is calculated by Bayer's method. The equation $r = f(u/c_0)$ has to be solved by the method of successive approximations, since at the commencement of the calculations the velocity coefficient in the working wheel Ψ and the adiabatic k.p.d. (efficiency) of stage η_s are unknown. The obtained curves $r = f(u/c_0)$ with various values for δ attain their maximum with $\beta_1 =$ 90°, that is when velocity w_1 is at a minimum. On these curves a curve is marked at the critical value of the parameter δ at which velocity w_2 becomes supersonic. A further increase in the degree of expansion has its genesis at the expense of the oblique section of the working blades. When the parameter u/c_0 is reduced the degree of reaction is reduced too and may drop to large negative values if the ratio u/c_0 is small. If the losses in the part of the turbine between the inlet and outlet valves are not taken into account then, in the region of changes of u/c_0 between zero and some value $(u/c_0)_{min}$, no degree of reaction will satisfy the joint solution of the equations of continuity and energy, while in the region $u/c_0 > (u/c_0)_{min}$ the functions $r(u/c_0)$ are obtained in a double-meaning form, which compels the author to use M. Rous's proposition in relation to the criteria of stability in thermodynamics and in gas dynamics to enable a selection to be made for the actual value of r. However there is no need for this, as in the region lower than the curve $M_{w_1} = 1$ drops to secure consolidation are inevitable and, consequently, even in an inviscid liquid losses occur, consideration for which eliminates the above-noted singularities in the development of the curves $r(u/c_0)$ and in particular the double meaning of those functions.

An analogous investigation was made for a two-link stage, which resulted in obtaining expressions for the calculation of the degree of reaction in the rims, and the conditions were also determined for the appearance of supersonic velocities in the part of a turbine between the inlet and outlet valves in a two-link stage.

V. Kh. Abiants

Courtesy Referativnyi Zhurnal, USSR

2600. Chzhuan, T.-D., Investigation of irregular regimes of work of a transparent hydro-transformer (in Russian), *Avtomob. Prom-st'* no. 8, 9–17, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10166.

Expressions are developed, on the basis of the one-dimensional theory of hydraulic machines, for the turbine moment, the pump moment and the moment on the driven shaft of a hydrotransformer working in an irregular regime, that is when angular acceleration and variations in the discharge of liquid by time intervals are operating. The theoretical results were verified experimentally on a ZIL hydrotransformer.

N. A. Kartvelishvili

Courtesy Referativnyi Zhurnal, USSR

2601. Rogener, H., Nondimensional numbers for the design and evaluation of acceptance tests of turbocompressors (in German), *Brennstoff-Wärme-Kraft* 12, 9, 377–379, Sept. 1960.

Since conditions prevailing for the acceptance tests of a turbocompressor may differ from the guaranteed values, author advocates conformation of some well-known dimensionless parameters.

L. S. Dzung, Switzerland

2602. Louis, Jean F., Secondary flow and losses in a compressor cascade, Aero. Res. Counc. Lond. Rep. Mem. 3136, 28 pp., 1960.

2603. Panov, Iu. L., Measurement of the instantaneous force acting on a blade of a vertical axis propeller, David W. Taylor Mod. Bas. Translation 300, 4 pp., Oct. 1960.

Author presents in summarized form a method and the results of measurements of the instantaneous normal component of the hydrodynamic forces acting on a single blade of a vertical axis propeller. An NACA symmetric blade profile with a semi-elliptic blade outline was used in the investigation. The results show that the normal forces in the second half of the orbit are generally smaller than in the first half.

From author's summary

Flow and Flight Test Techniques and Measurements

(See also Revs. 2317, 2551, 2601, 2644, 2674, 2813)

2604. Haszpra, O., Theory and application of proportional meters (in Hungarian), *Viz. Közl.* no. 4, 549-572, 1959.

Author supposes the knowledge of A, M and M/m in the relationships $\Delta b = A\ Q^M$ and $\Delta b = a\ q^m$, where Δb is the drop in head caused by the main constriction, Q and q the rate of flow in the main flow and in the shunt flow respectively, A, a, M and m are constants. It is shown that in the case of $M = m$ the multiplicator $n = Q/q$ is independent of Q. A formula is deduced for the mean value of the multiplicator $\bar{n}$ being $M \neq m$ and knowing the graph of the inverted flow duration function. Assuming a linear inverted flow duration function, a procedure is developed for the approximate calculation of $\bar{n}$. On the same basis an estimate of the error and two examples are also given. The results are summarized in a table. For installing proportional meters some very useful examples are given.

A. Verba, Hungary

2605. Vagas, I., On the evaluation of hydraulic measurements with dye-surges (in Hungarian), *Hidrológiai Közlöny* **39**, 6, 448-451, Dec. 1959.

For hydraulic measurements with dye stuffs in Hungary preference is given to the so-called flow-through curve method [AMR **12** (1959), Rev. 3951] over the dye-surge one generally used in other countries. Author developed an analytical relationship between the two curves. With this it is possible to trace the evaluation of the dye-surge curve back to that of the flow-through curve. Formulas are given for computing the so-called first and second efficiencies of settling tanks. They contain the time T of the injection of the dye-stuff which can not be determined exactly when using the dye-surge method. On an example an approximate determination of T from the shape of the dye-surge curve is shown.

Because of the uncertainty of T author considers the dye-surge method approximate only and suggests using the flow-through curve method. In reviewer's opinion the experimental comparison of the two methods should be useful.

A. Verba, Hungary

2606. Seddon, J., and Nicholson, L. F., The representation of engine airflow in wind-tunnel model testing, Aero. Res. Counc. Lond. Rep. Mem. 3079, 22 pp., 1960.

The problems of engine airflow representation in wind-tunnel models are reviewed. Methods which have been used satisfactorily in low subsonic tunnels are described briefly. Special difficulties associated with testing at transonic speeds are noted. Techniques of special application to small supersonic tunnels are described in some detail. It is shown that there are reasons why the representation of jets may be more important at supersonic speeds than at subsonic speeds and a description is given of the Royal Aircraft Establishment Jet Interference Tunnel, which is designed for the study of some of the problems involved.

From authors' summary

2607. Pohl, K. H., Flow relations in a diffuser with a curved tube (in German), *Ing.-Arch.* **29**, 1, 31-38, 1960.

This paper consists of an abstract of the author's thesis accepted in 1954 at the Max-Planck Research Institute of Göttingen for a doctor's degree. It studies flow relations in a diffuser with a curved tube. Basic experimental results of this research work carried out with air consist of the measurements of the pressure losses and in the drawing of velocity profiles.

In a diffusor of square cross section and 10° total extension angle there occurs a detachment in the channel arrangement without a curved tube. Considerable pressure losses are thereby produced. The experimental results show a reduction in pressure losses in a diffusor with a curved tube. Hence the pressure loss is smaller than the amount of the individual losses corresponding to the curved tube and the diffusor.

D. Mangeron, Roumania

2608. Sandri, R., A photo-electric device for the measurement of quantity of liquid, Nat. Res. Counc. Canada, Mech. Engng. Rep. MI-822, 4 pp. + figs., Sept. 1960.

2609. Cotton, K. C., and Westcott, J. C., Throat tap nozzles used for accurate flow measurements, *ASME Trans.* **82** A (*J. Engng. Power*) 4, 247-263, Oct. 1960.

2610. Zenkevich, V. B., The application of the similarity method to the study of the viscosity of liquid fuels (in Russian), *Inzbener.-Fiz. Zb.* **3**, 9, 56-60, Sept. 1960.

2611. Temple, E. B., The physical optical analysis and application of the schlieren interferometer, Mass. Inst. Technol., Nav. Supersonic Lab. Tech. Rep. 133, 161 pp., Aug. 1959.

By examining the wave optics description of the schlieren system, it is shown that interference effects can result which are quantitatively related to the density in a gas. The schlieren system thus becomes equivalent to an interferometer. Criteria are given for dimensions of light source and other components which will produce the desired interference fringes.

From author's summary

2612. Pocock, P. J., Non-aeronautical applications of low-speed wind tunnel techniques, Nat. Res. Counc. Canada, Mech. Engng. Rep. MA-243, 111 pp. + figs., Sept. 1960.

2613. Peckham, D. H., and Atkinson, S. A., Preliminary results of low speed wind tunnel tests on a Gothic wing of aspect ratio 1.0, Aero. Res. Counc. Lond. Curr. Pap. 508, 16 pp. + figs., 1960.

This note gives preliminary results of low-speed balance measurements and flow visualization tests, on a wing of aspect ratio 1.0. The wing had a convex parabolic leading-edge shape in plan view, and an unswept trailing edge; such wings are now termed "Gothic." All edges were sharp, the center section was 12% biconvex, and transverse sections were diamond-shaped.

Results of tests on a strictly comparable delta wing are not yet available, but where possible the results are compared with tests on other wings of aspect ratio 1.0 with unswept trailing edges.

From authors' summary

2614. Lessing, H. C., Troutman, J. L., and Menees, G. P., Experimental determination of the pressure distribution on a rectangular wing oscillating in the first bending mode for Mach numbers from 0.24 to 1.30, NASA TN D-344, 91 pp., Dec. 1960.

The results of an experimental investigation in a wind tunnel to obtain the aerodynamic pressure distribution on an unswept rectangular wing oscillating in its first symmetrical bending mode are presented. The wing was of aspect ratio 3 with 5-percent-thick biconvex airfoil sections. Data were obtained at 0° and 5° angle of attack in the Mach number range from 0.24 to 1.30. The experimental data are compared with oscillatory pressure distributions computed by means of the most complete linearized theories available.

From authors' summary

2615. Huntley, E., Wind tunnel measurements of normal force and pitching moment on four cone-cylinder combinations at transonic and supersonic speeds, Aero. Res. Counc. Lond. Curr. Pap. 507, 12 pp. + figs., 1960.

Wind-tunnel tests have been made, in the 3-ft × 3-ft tunnel, on four cone-cylinder models at Mach numbers between 0.70 and 2.00. The tip of each cone was rounded and the over-all fineness ratio of each model was less than 8.0.

The normal force and center-of-pressure characteristics of the models (the datum for the latter being the cone-cylinder shoulder) were found to be dependent primarily on cone angle. The effect of increasing the tip radius from 0.20 to 0.50 times the body radius was negligible at all speeds. From author's summary

Book—2616. Handbook of supersonic aerodynamics, Vol. 6, (Section 18), **Shock tubes** (Bureau of Naval Weapons Publication, NAVORD Rep. 1488), Washington 25, D. C., Superintendent of Documents, U. S. Government Printing Office, 1959, xxxviii + 604 pp. $3.75. (Paperbound)

This is a comprehensive and detailed account of shock tube theory and applications. The introduction and sections on the theory and performance of constant-area shock tubes and on viscosity and heat transfer effects are by I. I. Glass. Sections by J. G. Hall describe the production of strong shock waves, applications of shock tubes to aerodynamic testing and in aerophysics, shock tube design and construction and instrumentation techniques.

The book collects a wealth of material from scattered sources, many of them reports of limited availability. The bibliography appears to cover the open literature to 1958 quite thoroughly. The coverage is both wider in scope and more detailed than the monograph by Greene and Toennies [AMR **13**(1960), Rev. 823] on the chemical applications of shock-wave technique.

While this report will be very useful to the specialist, there is still a need for a comprehensive survey for the nonspecialist to acquaint him with the potential utility of shock-wave techniques in a variety of fields. W. Squire, USA

2617. Laporte, O., and Wilkerson, T. D., Hydrodynamic aspects of shock tube spectroscopy, *J. Opt. Soc. Amer.* **50**, 12, 1293–1299, Dec. 1960.

Time-resolved spectroscopic observations with the shock tube are described. Emission spectra are recorded for the high-temperature gas behind the shock reflected from the closed end of the tube. Simultaneous observations are made of the hydrodynamic variables. The state of the emitting gas is predicted by hydrodynamic theory and correlated with the observed spectrum. Deviations from ideal theory caused by viscosity and heat conduction are recognized, and their influence upon pressure and temperature is appraised by direct measurement.

From authors' summary

2618. Hartunian, R. A., Russo, A. L., and Marrone, P. V., Boundary-layer transition and heat transfer in shock tubes, *J. Aerospace Sci.* **27**, 8, 587–594, Aug. 1960.

Heat transfer to the wall of a shock tube was measured by thin film resistance thermometers. For the laminar part of the boundary layer the results agree with the theory of Mirels. Transition points and turbulent heat transfer also could be deduced from the measurements. Some dependency of transition Reynolds number on pressure is found. L. J. F. Broer, Holland

2619. Naeseth, R. L., An exploratory study of a parawing as a high-lift device for aircraft, NASA TN D-629, 31 pp., Nov. 1960.

A wind-tunnel investigation was made of the high-lift capabilities of two supersonic airplane configurations equipped with auxiliary parawings which are lightweight, stowable, fabric wings of parachute-like construction that may be used for take-off and landing.

The use of a parawing which had an area twice the wing area of the airplane model to which it was attached (canard bomber model) resulted in a threefold increase in lift coefficient at an airplane altitude of 12°. The static lateral stability characteristics of the canard airplane model were improved by adding the parawing. The use of a nonporous fabric in the construction of the parawings about doubled the lift-coefficient increment obtained with a parawing constructed of parachute cloth.

From author's summary

2620. Gaukroger, D. R., Wind-tunnel tests on the effect of a localised mass on the flutter of a swept-back wing with fixed root, Aero. Res. Counc. Lond. Rep. Mem. 3141, 29 pp., 1960.

Wind-tunnel tests to determine the flutter characteristics of a model wing, carrying a localized mass, are described. The investigation covers the effects of wing sweepback, and of the magnitude and position of the localized mass. Consideration is also given to the effects of pitching radius of gyration and aerodynamic shape. The mass values used vary from 0.13 to 1.17 times the wing mass. The test results indicate that the parameters that have the greatest effect on critical flutter speed are mass value, spanwise and chordwise position of the localized mass, and wing sweepback. Radius of gyration and aerodynamic shape of the localized mass are found to be secondary in their effects.

It was found that the flutter speed of a wing could be considerably increased or decreased by attaching a localized mass; under certain conditions the flutter speed could be more than doubled.

A number of different forms of flutter were obtained in the tests, and the values of the parameters at the transition from one form of flutter to another provide the main guide to the flutter characteristics of a wing carrying a localized mass.

From author's summary

2621. Clarke, J. F., The measurement of unsteady forces and moments on slender bodies oscillating in a wind tunnel, Aero. Res. Counc. Lond. Rep. Mem. 3170, 22 pp., 1960.

An apparatus for the measurement of unsteady aerodynamic reactions on slender bodies is described. It is particularly suited to tests at supersonic speeds. The forces and moments on the model are detected by strain-gages attached to the model mounting sting, and by supplying their bridge circuits with properly phased a c of the right frequency, direct meter readings of the stiffness or damping reactions may be obtained.

The results of a short series of tests on a cone-cylinder at subsonic Mach numbers and reduced frequency parameters (based on model length) up to 0.06 are given.

From author's summary

2622. Cox, A. P., Measurements of the velocity at the vortex centre on an A.R.I. delta wing by means of smoke observations, Aero. Res. Counc. Lond. Curr. Pap. 511, 4 pp. + figs., 1960.

Measurements have been made by using a smoke technique of the axial velocity near the center of the leading edge vortex on a delta wing of aspect ratio 1 at $\alpha = 20°$. By simultaneously breaking trails of smoke at the vortex center and in the free stream and analyzing a film of the result, it is shown that the velocity at the center is at least 40% higher than free stream. Near the trailing edge the velocity at the center decreases rapidly to approximately free-stream velocity. From author's summary

2623. Chisholm, R. G. A., Design and calibration of an air ejector to operate against various back pressures, Univ. Toronto, Inst. Aerophys. TN 39, 38 pp. + figs., Sept. 1960.

As part of a wind tunnel investigation of GETOL aerodynamics, an air ejector was designed and built to act as a "step-down transformer" between a high pressure air supply and the models. It consisted of a central primary jet discharging into a constant area mixing tube. The thrust and mass augmentation of this ejector were determined for various mixing tube back pressures. These

experiments were carried out for a convergent primary nozzle and a supersonic one and for two diameters of the mixing tube with the latter nozzle. The effect of the primary mass flow on the mass and thrust augmentation was obtained for a sonic primary.

A comparison was made between the experimental results and those predicted by a theory developed in this paper. The agreement between theory and experiment was generally within ten per cent except when the mixed velocity profile was very nonuniform.

From author's summary

2624. Arvidson, G., The vibrating cylinder pressure transducer, Flygmotor Aeroengine Co., TN 9, 5 pp. + charts, Dec. 1959.

2625. Gedeon, J., Longitudinal static stability measurements on sailplanes (in Hungarian), *Járművek Mezőgasdasági Gépek* **7**, 9, 349-360, Sept. 1960.

Author measures, on eight sailplanes, displacement of control stick and force on control stick in free flight, with locked and free controls. Values were calculated with graphical differentiation and plotted against lift. Investigations were made at traveling speed and high-speed gliding. Author gives optimum values:

Displacement of control stick = 40-60 mm Cy
Force on control stick = 1.5-1.6 kilogram
Friction force on control surface = 0.04 × (weight)$^{1/3}$.

G. A. Magony, USA

Thermodynamics

(See also Revs. 2553, 2632, 2680, 2683, 2726)

2626. Okano, K., Odd variables and thermodynamics, *Inst. Phys. Chem., Res. Scient. Pap., Tokyo* **54**, 1, 1-5, Mar. 1960.

This research aims to establish the possibility of quasi-static coupling between thermodynamic variables in a general way. Author formulates a necessary condition for a linear coupling to exist between variables of different parities; that is possible only when the reference state is in some way specified, to some extent, by variables of odd parity. It is said, however, that the restriction of linearity may be easily removed.

Author thereafter discusses briefly the theory of relaxation phenomena and of gyromagnetic effects. In the first case, he concludes [as Casimir and du Pré, *Physica* **5**, p. 507, 1938] that a spin-lattice relaxation process can only occur in paramagnetic substances if, at reference state, a magnetostatic field is present, or something of equivalent (odd) parity. In the second case, analysis of Einstein—de Haas and Barnett effects gives the relation: $\partial M/\partial\Omega = \chi V \gamma^{-1}$, where M stands for the magnetic moment, Ω the angular velocity of the sample, χ the magnetic susceptibility, V the volume of the body and γ the magneto-mechanical ratio, an expression that seems suitable for experimental test.

O. Cerceau, Venezuela

2627. Polock, B., Recompression with steam cycles (in German), *Brennstoff-Wärme-Kraft* **12**, 7, 304-311, July 1960.

The application of the recompression of water vapor with steam cycles is explained in connection with the methods of steam utilization so far known. The recompression method used by the Field process and the binary steam cycle are compared with each other as well as with a standard steam cycle of equal value. The consumption figures are presented and the most important points of difference are explained. The Austenite requirement is estimated and the steam wetness is investigated.

From author's summary

2628. Potthast, G., Energy gain by improvement of the vacuum in a condenser (in German), *Brennstoff-Wärme-Kraft* **12**, 7,311-314, July 1960.

The gain obtainable by vacuum improvement with condensing turbines is investigated. It is shown how much the gain depends on the absolute value of the vacuum and on the entropy value of the exhaust steam. A method of calculation is discussed where the essential calculation figures are prepared by diagrams. For cycles with regenerative reheating an equation is proposed which makes it possible, with the help of the pass-out steam throughputs and two data from a table, to obtain with reasonable approximation the gain of the total process.

From author's summary

2629. Bohn, H., Heat recovery in the wet steam region (in German), *Brennstoff-Wärme-Kraft* **12**, 7, 314-317, July 1960.

As the saturated steam turbines of nuclear reactors use saturated steam up to 600 lb/sq in., the article investigates how far the data for determining the heat recovery, which are applicable for the normal low pressure stages of condensing turbines with much lower pressures, are also valid for high pressures. It is shown that the heat recovery for a wider pressure range depends on the initial pressure. A nomogram for the extended pressure range is developed for the heat recovery in the wet steam region.

From author's summary

2630. Brokaw, R. S., Alignment charts for transport properties; viscosity, thermal conductivity, and diffusion coefficients for nonpolar gases and gas mixtures at low density, NASA TR R-81, 34 pp., 1960.

2631. Bernasconi, S., and Gotsch, G., Condensation of different vapors during adiabatic expansion (in German), *ZAMP* **10**, 5, 509-519 (Brief Reports), Sept. 1959.

Paper describes experiments to determine time lag of condensation relative to pressure variation in adiabatically expanding air after saturation with vapors of water, ammonia, or acetone has been exceeded. This lag was found exceedingly small for all vapors tested, and degrees of supersaturation in expansion chambers were considerably below critical saturation even for smallest nuclei. A possible quantitative evaluation of results will be published elsewhere.

R. J. Hakkinen, USA

2632. Stillinger, F. H., Jr., Approximations in the theory of dense fluids, *Physics of Fluids* **3**, 5, 725-732, Sept./Oct. 1960.

2633. Tyrrell, H. J. V., Some problems associated with the definition of the heat of transfer for binary liquid systems, *Trans. Faraday Soc.* **56**, 6, 450, 770-775, June 1960.

An attempt to provide a consistent thermodynamic treatment of the heat of transfer was made from the point of view of macroscopic Soret effect and the microscopic point of view of kinetic theory. The concentration dependence of the quantity Q^*/N (Q^* is the heat of transfer and N is the mole-fraction) in the two cases was suggested as a point of difference or uncertainty. This is believed to be accountable by considering the interaction among the elemental particles of the systems. In liquids, strong interaction is expected; Q^*/N would be, in general, concentration-dependent. In a dilute gas and in the limit in an ultra-high vacuum, interactions among particles within the adsorbed phase and among the free molecules themselves are weak; transfer involves mainly interaction between the phases, and Q^*/N is independent of concentration. Increased interaction when concentration is increased gives various extents of such dependence.

S. L. Soo, USA

2634. Butenko, G. F., and Radchenko, M. I., The application of the theory of thermodynamic similarity to the determination of physical properties of liquid metals (in Russian), *Inzbener. Fiz. Zb.* **3**, 6, 66–71, June 1960.

2635. Helfand, E., On inversion of the linear laws of irreversible thermodynamics, *J. Chem. Phys.* **33**, 2, 319–322, Aug. 1960.

This essentially mathematical note deals with the problem of inverting a symmetric singular matrix. Hence linear laws of irreversible thermodynamics may be inverted despite singular nature of admittance matrix when barycentric diffusion currents are employed. Results would probably have been of greater value to engineers and physicists if equations (3.9), (3.10) had been expressed as relations between components of the vectors and matrices concerned.

M. A. Jaswon, England

2636. Miller, D. G., Thermodynamics of irreversible processes—the experimental verification of the Onsager reciprocal relations, *Chemical Reviews* **60**, 1, 15–37, Feb. 1960.

To one familiar with the sound statistical foundations of the Onsager reciprocal relations there seems to be little motivation for the pursuit of experimental tests. However, because of controversial theoretical origins, such tests have always been a prolific area of study for the experimental chemist. This exhaustive review gives voice to this prolificity and, not surprisingly, concludes that the relations are experimentally verified. Good confirmation has been obtained in the processes of thermoelectricity, electrokinetics, isothermal diffusion, and anisotropic heat conduction. In other processes where the accuracy of the data is limited, no unequivocal experimental statement is yet possible. The review will certainly fulfill a useful role by hastening the conversion of the reciprocal relations from that of a scientific curio to a powerful predictive theoretical relation.

J. S. Kirkaldy, Canada

2637. Watson, K. M., Bludman, S. A., and Rosenbluth, M. N., Statistical mechanics of relativistic streams: Parts 1 and 2, *Physics of Fluids* **3**, 5, 741–757, Sept./Oct. 1960.

2638. Grashdankina, N. P., Domanskaya, L. I., and Kikoin, A. K., Measurements of temperature in high-pressure chambers by means of thermistors, *Measurement Techniques* no. 10, 771–774, Aug. 1960. (Translation of *Izmeritel'naya Tekbnika USSR* no. 10, 18–20, Oct. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Heat and Mass Transfer

(See also Revs. 2311, 2318, 2335, 2336, 2459, 2546, 2566, 2569, 2573, 2574, 2618, 2633, 2635, 2690, 2714, 2724, 2725, 2730, 2762, 2777, 2795)

2639. Elrod, H. G., Jr., Improved lumped parameter method for transient heat conduction calculations, *ASME Trans.* **82** C (*J. Heat Transfer*), 3, 181–188, Aug. 1960.

A general mathematical method is presented for obtaining approximate solutions for the main features of the response of thermal systems. The method is illustrated by application to transient heat conduction in slabs and cylindrical rods, for which mean and surface temperatures of one face are suddenly lowered. Agreement with analytical results is good. The method depends on the existence of a convolution integral relating the response and forcing functions. It t is the time and u the variable of integration, the forcing unit step-function $G(t-u)$ occurring in the convolution integral is expanded as a Taylor series in u as far as u^2. A mathematical justification of the process, and subsequent steps, is given. The physical reasoning leading to the method is that in damped linear systems past history effects of $G(t)$ tend to fade away leaving only recent values to produce the dominant effect.

Reviewer believes this to be an important paper in the theory of heat transfer, introducing a method which might also be applicable to other forced, damped, linear systems for which reasonably accurate, but not detailed, solutions are required.

R. P. Pearce, Scotland

2640. Vodicka, V., Steady temperature in an infinite multilayer plate (in English), *ZAMM* **40**, 4, 161–165, Apr. 1960.

Equations are derived for the steady-state temperature distribution in an infinitely long, two-dimensional, multilayer slab with any prescribed, but periodic, temperature variation along each surface. Standard separation-of-variables technique is employed to obtain the infinite-series solution; no numerical results are presented.

R. R. Heldenfels, USA

2641. Vodicka, V., Stationary temperature fields in multilayer cylindrical tubes (in English), *ZAMM* **40**, 4, 165–170, Apr. 1960.

A simple transformation procedure is used to convert the periodic, steady-state temperature distributions derived in preceding review to the cylindrical conduit case. Exact equations are presented for circular cross sections and approximate ones for elliptical shapes.

R. R. Heldenfels, USA

2642. Deeg, E., and Hertweck-Crone, Irene, Computation of nonstationary temperature distribution in layered media, with the help of electric analog computers (in German), *Z. Angew. Phys.* **12**, 4, 184–190, Apr. 1960.

Problem treated relates to the premoulding of glass melt into the form of hollow, essentially cylindrical objects, such as bottles. Its purpose is to determine the nonsteady temperature fields, in both the mould and the glass object, which arise in this typically intermittent process, consisting of a long series of cycles. For a few representative cases this axially symmetrical problem is solved by means of an electronic analog computer, and attention is given particularly to the average temperature at the inner surface of the mould, this being significant for the quality of the final product. It is found that this temperature is more sensitive toward the duration of each cycle than toward the cooling at the outside of the mould.

H. Blok, Holland

2643. Stainback, P. C., Heat-transfer measurements at a Mach number of 4.95 on two 60° swept delta wings with blunt leading edges and dihedral angles of 0° and 45°, NASA TN D-549, 50 pp., Jan. 1961.

The laminar-flow heat-transfer distribution (ratio of local to stagnation-line heating rate) around the wing normal to the leading edge and the stagnation-line heat-transfer level were compared with two-dimensional blunt-body theory. A comparison was made of the heat-transfer levels to the two wings at equal angles of attack and equal lifts. The tests were conducted at a stagnation temperature of 400° F, and the test-section unit Reynolds number was varied from 1.95×10^6 to 12.24×10^6 per foot. The angle of attack was varied from 0° to 20° for the two configurations.

From author's summary

2644. Gunn, C. R., Heat-transfer measurements on the apexes of two 60° sweptback delta wings (panel semiapex angle of 30°) having 0° and 45° dihedral at a Mach number of 4.95, NASA TN D-550, 51 pp., Jan. 1961.

The laminar heat-transfer distributions (ratio of local to stagnation-line heating rate) about the models normal to the cylindrical leading edges were in close agreement with two-dimensional blunt-body theory. Comparison of heating rates on the two models at

equal angles of attack and equal lifts demonstrated the reduction in stagnation-line heating that may be realized when large dihedral is incorporated into a 0° dihedral swept wing. The tests were conducted at a Mach number of 4.95 and a stagnation temperature of 400° F. The nominal test-section unit Reynolds number varied from 2×10^6 to 12×10^6 per foot. Angles of attack of the 0° and 45° dihedral wings varied from 0° to 15° and 0° to 20°, respectively. From author's summary

2645. von Glahn, U. H., Empirical equation for turbulent forced-convection heat transfer for Prandtl numbers from 0.001 to 1000, NASA TN D-483, 16 pp., Dec. 1960.

A review is made of some of the experimental data and analyses applicable to convective heat transfer in fully turbulent flow in smooth tubes with liquid metals and viscous Newtonian fluids. An empirical equation is evolved that closely approximates heat-transfer values obtained from selected analyses and experimental data for Prandtl numbers from 0.001 to 1000. The terms included in the equation are Reynolds number, Prandtl number, and an empirical diffusivity ratio between heat and momentum.

From author's summary

2646. Granville, R. A., and Boxall, Genefer, Measurement of convective heat transfer by means of the Reynolds analogy, *Brit. J. Appl. Phys.* **11**, 10, 471–475, Oct. 1960.

Preston's method for measuring skin friction in pipes has been extended to include nonuniform flow, with and without pressure gradients, over flat surfaces. By means of a modified form of the Reynolds analogy, the local convective heat-transfer coefficient can be related to the skin friction, and it is proposed that the method be used in aerodynamic models of furnaces and in heat-transfer plant of simple geometry. More investigations are required of the effects of fluid turbulence, surface roughness and surface curvature on convective heat transfer and skin friction.

From authors' summary

2647. Tien, C. L., Heat transfer by laminar flow from a rotating cone, *ASME Trans.* **82** C (*J. Heat Transfer*), 3, 252–253 (Tech. Briefs), Aug. 1960.

By using simple transformations, author shows how to determine the heat transfer with a laminar boundary layer over rotating cones from knowledge of the heat transfer over rotating disks. The analysis covers incompressible and compressible flow.

E. Sunderland, USA

2648. Kosterin, S. I., and Koshmarov, Y. A., The choice of determining temperature in calculating convective heat transfer and friction in dynamic gas conditions (in Russian), *Inzhener. Fiz. Zh.* **3**, 7, 3–9, July 1960.

2649. Stephan, K., Analysis of the heat transfer and pressure drop for laminar flow in entrance regions (in German), *Ing.-Arch.* **29**, 3, 176–186, June 1960.

The problem of laminar flow in the entrance regions of infinite parallel plates and circular pipes is considered analytically in order to calculate the heat transfer and pressure drop. The case of coincidentally-starting flow and thermal boundary layers is specified, and the fluid properties are held constant, which enables the author to solve independently the boundary-layer equations of continuity, momentum and energy.

Exact solutions are obtained by means of a series expansion of the stream and the temperature ratio, for Prandtl numbers of 0.1, 1, 10. Approximate solutions are used to obtain results for Pr of 100 and 1000. Axial conduction is neglected in all cases.

Calculated results are presented in terms of the average Nusselt number plotted against the inverse of the product of the Reynolds number and a diameter-to-tube-length ratio, with Prandtl number as a parameter for the pipe, and similar results for the parallel plates. The results show correspondence to plane flat plates near the entrance, while farther downstream they fair nicely into the results of Graetz-Nusselt for fully developed laminar flow.

R. M. Drake, Jr., USA

2650. Reynolds, W. C., Heat transfer to fully developed laminar flow in a circular tube with arbitrary circumferential heat flux, *ASME Trans.* **82** C (*J. Heat Transfer*), 2, 108–112, May 1960.

A solution is presented for fully developed laminar heat transfer in a circular tube with arbitrary circumferential heat flux. Examples included indicate that the influence of circumferential heat-flux variation on wall temperatures can be quite significant and provide some insight into the nature of the effects. The analysis allows calculation of wall temperatures for any arbitrary peripheral heat-flux variation for fully developed laminar flow under the restriction of constant axial heat input. [From author's summary]

Reviewer's note: Flow has been assumed to be of the Poiseuille type, and natural convection has been neglected. Equation [32] may be conceived as an integral equation for the inverse problem, where the circumferential wall-temperature distribution is given and the corresponding heat flux distribution is required.

H. Blok, Holland

2651. Nakagawa, Y., Heat transport by convection, *Physics of Fluids* **3**, 1, 82–86, Jan./Feb. 1960.

Author uses the integral method, which was used earlier by Malkus and Veronis [AMR **12**(1959), Rev. 1506], to calculate an approximation to the heat transfer in (rectangular) cellular convection between horizontal parallel planes as a function of the Rayleigh number. For the case of free-free boundary conditions the author's result agrees with that of Malkus and Veronis. For the case of rigid-rigid boundary conditions, it is not clear to this reviewer that the results of the author and of Malkus and Veronis are in agreement; the author makes no comment on this.

There is no discussion of the approximations involved in the integral method, a matter which can be evaluated qualitatively by reference to the series method used by Malkus and Veronis (see, for example, p. 242 of their paper quoted above). Moreover the author makes no comparison of his theoretical results with experiment. J. T. Stuart, England

2652. Nakagawa, Y., Heat transport by convection in presence of an impressed magnetic field, *Physics of Fluids* **3**, 1, 87–93, Jan./Feb. 1960.

Author extends the use of the Malkus-Veronis integral method for heat transfer in thermal convection (see previous review) to the case of a conducting fluid in the presence of a magnetic field. As in the paper of the preceding review, rectangular cells only are considered. J. T. Stuart, England

2653. Gadd, G. E., Cope, W. F., and Attridge, J. L., Heat-transfer and skin-friction measurements at a Mach number of 2.44 for a turbulent boundary layer on a flat surface and in regions of separated flow, Aero. Res. Counc. Lond. Rep. Mem. 3148, 40 pp., 1960.

2654. Goldstein, R. J., and Eckert, E. R. G., The steady and transient free convection boundary layer on a uniformly heated vertical plate, *Inter. J. Heat Mass Transfer* **1**, 2/3, 208–218, Aug. 1960.

A Zehnder-Mach interferometer was used to study the free-convection thermal boundary layer about a uniformly heated vertical plate and to derive the heat-transfer coefficients connected with this situation. The experiments were performed when the plate was immersed in water and the steady-state boundary layer, as well as its transient development from an initial state at rest and

with unifom temperature to steady-state condition, was investigated when a step function in the power input to the plate was applied. Results for the steady-state runs agree very well with the results of an analysis by Sparrow and Gregg. The transient runs indicate that the temperature field in the fluid develops initially in the same way as for heat conduction into a semi-infinite solid. After a short transition period, the steady-state condition is reached. The boundary layer grows with time in such a way that it increases at first with increasing time, reaches a maximum, and decreases again until it settles to its steady-state value. The wall temperature and the local heat-transfer coefficient can be predicted for the whole period from start to steady state by the solution for one-dimensional unsteady conduction or for the steady-state boundary layer.

From authors' summary by M. Finston, USA

2655. Braun, W. H., and Heighway, J. E., An integral method for natural-convection flows at high and low Prandtl numbers, NASA TN D-292, 40 pp., June 1960.

Integral method is applied to natural convection on a vertical semi-infinite flat plate, the plate being maintained at a higher temperature than the ambient gas. Methods are developed for both low and high Prandtl numbers, and the heat transfer obtained is in much better agreement with exact calculations than are results of earlier approximate methods. For mass flow, agreement with exact calculations is a little less satisfactory, but still demonstrably better then was the case with earlier approximate methods.

J. T. Stuart, England

2656. Sevryk, I. G., Uniqueness of the solution of the fundamental problem of the free thermal convection of a liquid (in Russian), *Izv. Vyssb. Ucbebn. Zavedenii Matematika* no. 4, 218–221, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10269.

Assuming that there is a solution, author demonstrates a theorem of the uniqueness of the following nonlinear boundary problem, describing the nonstationary free convection of an incompressible liquid in a closed space V

$$\frac{\partial y}{\partial t} + (v\nabla)v = -\nabla\frac{p}{q} + \psi\,\Delta v - \beta g T$$

$$\operatorname{div} v = 0, \quad \frac{dT}{dt} = \chi\Delta T$$

$$v_s = 0, \qquad T_s = \varphi(r, t), \qquad v_o = f(r), \qquad T_o = \psi(r)$$

where v is the vector of velocity of the liquid, p is reckoned from the hydrostatic pressure of the liquid, T is the temperature of the liquid reckoned from some known datum line, g is the earth's acceleration, q is the density of the liquid, ν, β, χ are the coefficients of the kinematic viscosity, thermal expansion and the temperature conductivity of the liquid respectively. The index s indicates the boundary, o the initial value of the corresponding magnitude. The proof for the theorem is accomplished by analogy with the proof of the theorem of the uniqueness of the solution of the basic boundary problem for a viscous incompressible liquid carried out by D. E. Dolidze [*Dokladi Akad. Nauk SSSR (N.S.)* **96**, 3, 437–439, 1954]. It should be noted that by using the ordinary method of boundary transition from the finite to the infinite region with the corresponding conditions to infinity the proof of the theorem of uniqueness can be extended to embrace the case of the external problem.

G. A. Tirskii

Courtesy Referativnyi Zburnal, USSR

2657. Sal'nikov, I. E., The course taken by convection when temperature waves are propagating in the liquids (in Russian), *Trudi Gor'kovsk. In-ta Inzb. Vodn. Transp.* no. 15, 136–154, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10268.

The problem is investigated of the propagation of temperature waves in a homogeneous layer of incompressible liquid, in a one-dimensional setting. A field, determined by the harmonic principle of a change of temperature at the boundary of the layer, is superimposed on the temperature field having a constant gradient. The Rayleigh criterion for a plane horizontal layer, determining the beginning of natural convection, is applied to the temperature waves produced as the result of the above manipulation. But a number of assumptions have to be made. The temperature gradient variable over the layer is replaced by the mean gradient. The boundaries of the layer variable with time are determined by means of the equation for heat conductivity. Criteria are obtained determining the commencement of convection. The course taken by the convection is studied.

K. K. Vasilevskii

Courtesy Referativnyi Zburnal, USSR

2658. Ornatsky, A. P., The effect of length and diameter of a pipe on the value of critical thermal flow at forced motion of water heated below saturation temperature (in Russian), *Teploenergetika* no. 6, 67–69, June 1960.

2659. Woodward, T., Heat transfer in a spray column, *Cbem. Engng. Progr.* **57**, 1, 52–57, Jan. 1961.

Pilot-size columns operated as direct liquid-liquid heat exchangers show that the heat-transfer coefficient depends on hold-up and on fluidity of the hydrocarbon exchange medium. If a suitable heat-exchange liquid can be found, spray columns may prove to be efficient heat exchangers for saline water conversion.

From author's summary

2660. Brown, G. M., Heat or mass transfer in a fluid in laminar flow in a circular or flat conduit, *AIChE J.* **6**, 2, 179–183, June 1960.

Accurate solutions to the Graetz equation and to the similar equation for flow between two parallel plates are presented, including the first ten or eleven eigenvalues and important derivatives. The first six eigenfunctions are also presented at intervals of 0.05 from $y = 0$ to $y = 1$.

From author's summary by F. L. Schuyler, USA

2661. Lamm, O., Diffusion coefficient and friction in a general two-component fluid, *Trans. Faraday Soc.* **56**, 6, 450, 767–769, June 1960.

Author uses "induction" in the theory of diffusion by combining the latter with the method of irreversible thermodynamics and simplifying of result. Although the claim includes the case of variable partial volumes, the derivation of the condition that the diffusion coefficient be symmetric is based on the condition of constant partial volumes. It was not clarified as to what is meant by "general property of partial quantities," and the basis for writing a total derivative in two parts, both equal to zero.

S. L. Soo, USA

2662. Prudnikov, A. P., Investigation of heat and mass exchange in dispersed media (in Russian), *Inzbener.-Fiz. Zb.* **1**, 4, 81–86, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10281.

The problem on the heat and mass exchange of dispersion systems in a porous medium is merged with the system of three linked equations of the type found in the equations for heat conductivity. Where there is a single three-dimensional variable the system is solved by the method of the successive application of the Fourier and Laplace conversions. The reverse conversions and the carrying out of the boundary conditions lead to a Volterra system of integral equations of the first order with singular nuclei. The latter merge with Volterra integral equations of the second order.

V. I. Merkulov

Courtesy Referativnyi Zburnal, USSR

2663. Liu, C.-Y., On minimum-weight rectangular radiating fins, *J. Aerospace Sci.* **27**, 11, 871–872 (Readers' Forum), Nov. 1960.

2664. Hanel, R. A., The dielectric bolometer, a new type of thermal radiation detector, NASA TN D-500, 10 pp., Nov. 1960.

Thermal detectors for the infrared, such as thermocouples and bolometers, are limited in their ultimate sensitivity predominantly by Johnson noise rather than temperature noise.

The dielectric constants of some materials are sufficiently temperature-dependent to make a new type of bolometer feasible. The basic theory of a dielectric bolometer promises noise figures below 3 decibels even at chopper frequencies well above the $1/\tau$ value of the detector. Ferroelectrics such as barium-strontium titanate and others seem to be well suited for radiation-cooled dielectric bolometers. From author's summary

2665. Howe, J. T., Radiation shielding of the stagnation region by transpiration of an opaque gas, NASA TN D-329, 24 pp., Sept. 1960.

Author summarizes: "The laminar compressible boundary layer in ... stagnation regions has been analyzed to show the effects of the injection of a radiation-absorbing foreign gas .... Total heat transfer to the stagnation region is evaluated for numerous cases, and the results are compared with the no shielding case. Required absorption properties of the foreign gas are determined and compared with properties of known gases."

Author points out several important assumptions in the analysis:

(1) "The surface of the vehicle ... adsorbs all incident radiation ... (and) ... emits no radiation."

(2) "The radiant energy emitted by the absorbing gas ... (is neglected)."

Reviewer agrees with author that the analysis presented is a limiting case. J. G. Bartas, USA

2666. Svet, D. Ya., New methods for determining the emissivity and reflectivity coefficients and the actual temperature of a self-radiating surface, *Soviet Phys.-Doklady* **4**, 6, 1375–1377, May/June 1960. (Translation of *Doklady Akad. Nauk SSSR (N.S.)* **129**, 6, 1290–1292, Nov./Dec. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Paper describes how the author's double spectral-ratio pyrometer could be used to measure the radiation characteristics and temperature of a surface which reflects diffusely. The method applies equally well when two bichromatic pyrometers are employed. The derived equations are essentially the same as those developed in Pepperhoff's book [W. Pepperhoff, "Temperaturstrahlung," Steinkopff, Darmstadt (1956), pp. 174–188]. The main feature of the method outlined here is that the values of the spectral emissivity of a surface are not determined from the absolute value of the spectral reflectivities but from the ratio of the reflectivities for different wavelengths. Although he does not describe his instrument in this paper, author claims it measures this ratio and the respective color temperatures simultaneously. When the surface is grey, the second method which he proposes is the same as that outlined by Pepperhoff.

Reviewer feels that papers describing the instrument would be of interest to workers in this field.

T. W. Hoffman, Canada

2667. Steinle, H. F., An experimental study of the transition from nucleate to film boiling under zero gravity conditions, Proc. Heat Transf. Fluid Mech. Inst., Stanford, Calif., June 15–17, 1960; Stanford Univ., 1960, pp. 208–219.

Drop tests of an electrically heated platinum wire horizontally submerged in Freon 114 were performed to study the transition from nucleate to film boiling under zero-gravity conditions at atmospheric pressure. The change of the wire temperature as a function of time was recorded by use of an oscillograph. The drop distance gave an approximate zero-gravity condition for about 0.75 seconds. Data relating heat flux to temperature difference between heater and liquid were compared with the one-g condition.

With the heating rates used in this study, boiling under zero g started sooner as well as at a lower heating rate than under one g. Nucleate boiling appeared to be time-dependent. Film boiling occurred with repeatability in zero g, at heat fluxes which could permit only nucleate boiling under one g; it follows that the transition from nucleate to film boiling is clearly sensitive to the gravitational acceleration. Due to the time dependence of the nucleate period, no clear boiling transition point from nucleate to film boiling was found under zero g.

From author's summary by P. P. Heusinger, Germany

2668. Mirzoeva, L. M., Experimental determination of the coefficient of heat emission of a continuous two-phase flow (gas-solid substance) (in Russian), *Doklady Akad. Nauk AzerbSSR* **14**, 10, 753–759, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10256.

An empirical relationship is derived between the criteria of Nusselt, Prandtl and Reynolds on the basis of experimental studies of the influence on heat exchange of the dimensions and concentration of the solid particles, of the velocity of the transporting phase, and of the temperature of the mixture.

From author's summary

Courtesy Referativnyi Zhurnal USSR

2669. Borishanskii, V. M., Coefficients of heat emission in boiling water at very high pressures (in Russian), *Energomashinostroenie* no. 7, 5–9, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10276.

An investigation is carried out of the heat emission when water and ethyl alcohol are boiling in horizontal tubes, made of stainless steel with a diameter of from 5–7 mm and with a length of 200 mm, placed in a large space. The pressure for the water is from 1 to 200 atm and for the ethyl alcohol from 1 to 60 atm. The thermal load was from 50×10^3 to 1×10^6 kcal/m²hr. The experimental apparatus is described and curves are supplied to show the relation of the coefficient of heat emission to the thermal load and the pressure. P. I. Povarnin

Courtesy Referativnyi Zhurnal, USSR

2670. Discrepancies between design and operation of heat transfer equipment (a panel discussion), *Chem. Engng. Progr.* **57**, 1, 71–80, Jan. 1961.

2671. Luzsa, I., Economical dimensioning of wall thickness of the superheating tubes (in Hungarian), *Energia es Atomtechnika* **13**, 10/11, 444–458, Oct. 1960.

2672. Fastovsky, V. G., and Petrovsky, U. V., Heat transfer and the resistance of pipe bundles arranged in chessboard order (in Russian), *Teploenergetika* no. 6, 69–72, June 1960.

2673. Novikov, M. D., The design of regenerator for gas turbine installation with the variable mode of operation (in Russian), *Teploenergetika* no. 6, 36–38, June 1960.

2674. Siviter, J. H., Jr., and Strass, H. K., An investigation of a photographic technique of measuring high surface temperatures, NASA TN D-617, 15 pp., Nov. 1960.

A photographic method of temperature determination has been developed to measure elevated temperatures of surfaces. The technique presented herein minimizes calibration procedures and permits wide variation in emulsion developing techniques. The present work indicates that the lower limit of applicability is approximately 1400° F when conventional cameras, emulsions, and

moderate exposures are used. The upper limit is determined by the calibration technique and the accuracy required.

From authors' summary

2675. Clark, D. D., Notes on the derivation of true air temperature from aircraft observations, Aero. Res. Counc. Lond. Rep. Mem. 3126, 11 pp., 1960.

2676. Irvine, T. F., Jr., edited by, A six-part survey—Rocket heat-transfer literature, *ASME Trans.* **82** C (*J. Heat Transfer*), 3, 155-169, Aug. 1960.

The survey is divided into the following parts: Rocket-engine heat sources; rocket cooling techniques; nozzle wall materials; variable fluid-property effects; predictions of thermal properties; flow separation and acoustic effects.

From author's summary

2677. Robbins, W. H., Bachkin, D., and Medeiros, A. A., An analysis of nuclear-rocket nozzle cooling, NASA TN D-482, 24 pp., Nov. 1960.

A nuclear-rocket regenerative-cooling analysis was conducted over a range of reactor power of 46 to 1600 megawatts and is summarized. Although the propellant (hydrogen) is characterized by a large heat-sink capacity, an analysis of the local heat-flux capability of the coolant at the nozzle throat indicated that, for conventional values of system pressure drop, the cooling capability was inadequate to maintain a selected wall temperature of 1440° R. Several techniques for improving the cooling capability were discussed, for example, high pressure drop, high wall temperature, refractory wall coatings, thin highly conductive walls, and film cooling. In any specific design a combination of methods will probably be utilized to achieve successful cooling.

From authors' summary

2678. Iberall, A. S., Human body as an inconstant heat source and its relation to determination of clothes insulation: Part 1, Descriptive models of the heat source; Part 2, Experimental investigation into dynamics of the source, *ASME Trans.* **82** D (*J. Basic Engng.*), 1, 96-112, Mar. 1960.

A precise characterization of the thermal resistance of clothes requires an accurate description of the static and dynamic thermal characteristics of the human-heat source. Experimental measurements on the human have revealed a frequency spectrum of sustained thermal power oscillations that mask theoretical long-time equilibrium adjustments. This points to the number of degrees of freedom that must be involved in the thermoregulation of the human, and the specific nonlinear characteristics of the system. Therefore at best, a resistance model for clothes is possible only as an ohmic relation among time-averaged equilibrium values, and for a specific mode of operation of the system. The validity of this hypothesis, however, has not been proved.

Quantitative measurement on the human in the so-called evaporative, vasomotor, and metabolic control regimes has revealed frequency spectrum of sustained thermal power oscillations with approximate periods of 2, 7, 35 min, and 3½ hr independent of the regime. Step function adjustments take place with a time constant of about 7 min. It is believed that the 3½ hr cycle represents the shortest equilibrium cycle. The hypothesis that it might be possible to measure the resistance of clothing as an ohmic relation among time-averaged equilibrium values, and for a specific mode of operation of the system has now been put in rational context in the time domain. Two equilibrium modes of the human system were explored. The active mode of operation of the system, to which the resistance concept of clothes is most applicable, is as a feedback system in which the extremities are used as error indicators of deviations from a comfort level set point. In response to deviations, the human feeds back a signal to generate an activity level in which only internal work—immediately degraded into heat—is done to maintain the comfort level. This is referred to as the comfort mode of operation of the system. Another "survival" mode of operation of the system is also described.

From author's summary

Process engineering (annual survey) (in German), *ZVDI* **102**, 28, Oct. 1960: (Revs. 2679 to 2687)

2679. Schiefer, K., 25 years of process engineering, p. 1329.

2680. Gunther, K. G., Vacuum engineering, p. 1330.

2681. Heinrich, W., Heat exchangers and evaporators, 1331-1333.

2682. Gorling, P., Drying practice, 1333-1334.

2683. Schaurer, G., High pressure engineering, 1334-1335.

2684. Rumpf, H., Comminution, 1335-1338.

2685. Barth, W., Screening, sifting and separating, 1338-1339.

2686. Batel, W., and Werner, S., Mechanical separation of fluids, 1339-1340.

2687. Erdmenger, R., Mixing and blending, 1340-1343.

Combustion

(See also Rev. 2553)

2688. Iinuma, K., Spark ignition of a fuel spray, Tech. College, Hosei Univ. Tokyo, Rep. 7, 21 pp., Mar. 1960.

Fuel sprays can be ignited by (1) hot air, (2) hot surface, (3) electric spark, (4) shock wave. Present research deals with spark ignition of a spray, injected by a pintle-type nozzle, into atmospheric air. Ignition delay is composed of (a) physical delay during which the jet disintegrates, vaporizes, and mixes with air, and (b) chemical delay during which pre-flame oxidation takes place. Author illustrates and describes the experimental apparatus which permits varying the instant of spark occurrence relative to the injection of spray within 20 to 300 milliseconds. He defines ignitibility as the ratio of the number of actual ignitions to the number of injections, as determined by 50 tries under the same conditions. Author used seven different fuels, and numerous spark positions, located at various axial distances from the nozzle, and at various lateral distances from the spray axis. Paper presents theory based on evaporation and diffusion. Two sets of experiments were made: (1) with single spark, using an ignition coil, and (2) with repeated sparks, using a magneto. Experiments show that ignitibility is highest at the center of the spray cone, and that nearly 100 per cent ignitibility can be attained, irrespective of fuel types, by using proper timing and spark locations.

This is competent research within its limited scope; it would be desirable to extend the conditions to a range of high temperatures, and a range of higher than atmospheric pressures, in order to approach more closely conditions existing in engines.

K. J. DeJuhasz, USA

2689. Rud'ko, A. K., The constructional limits of the propagation of a flame in a laminar two-phase mixture (in Russian), Combustion in two-phase systems, Moskva, Akad. Nauk SSSR, 1958, 26-49; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 9799.

In order to carry out a theoretical investigation of a flame front propagating in a two-phase system, three zones are set up: the zone of heating, the zone of kinetic combustion of the vaporized

fuel and the zone of diffused combustion of drops of the fuel. The flow of heat transmitted from the more highly heated zone of diffusional combustion to the zone of kinetic combustion results in an increase of velocity of propagation of the flame and in an expansion of the concentration limits of the ignition of the two-phase mixture as compared with the homogeneous mixture, in which the maximum temperature of the flame is equal to the temperature on the boundary of the kinetic zone and the diffusion zone of the two-phase mixture. The flow of heat from the burning vapor phase in the kinetic zone to the drops of fuel leads to a slowing-up of the chemical reaction of combustion in the vapor phase. The author, on the basis of this presentation of the problem, undertakes a theoretical determination of the concentration limits for the ignition of two-phase mixtures of ethyl alcohol and air, using different correlations between the concentrations of the liquid and vapor phases, with different degrees of dispersion, pressures and temperatures. The experimental investigation confirmed the basic deductions of the theory: (1) The upper concentration limit for the ignition of two-phase mixtures with a stoichiometric composition for the vapor phase is 3 to 4 times greater than in the homogeneous mixture, if the mean diameter of the drops is not less than 100μ. (2) Finely-dispersed mixtures ignite even at zero concentrations of the fuel in the vapor phase, but to ensure ignition in coarsely-dispersed mixtures a determined minimum concentration for the vaporized fuel is an essential. (3) If the concentration of vaporized fuel in the two-phase mixture exceeds the upper concentration limit of the homogeneous mixture then the two-phase mixture will not ignite. (4) Consequent on increases of temperature or pressure the concentration limits of the two-phase mixture tend to widen somewhat.

L. S. Dmitriev

Courtesy Referativnyi Zhurnal, USSR

2690. Chambre, P. L., On chemical reactions in internal flow systems, *Appl. Scient. Res.* (*A*) **9**, 2/3, 157-168, 1960.

A theoretical analysis is made of a slowly reacting fluid in an axially symmetric internal flow system. The flow is assumed to be steady and fully developed, with constant fluid properties, so that the velocity profiles are known. All binary diffusion coefficients are considered equal, and the Lewis number is set equal to unity. Dissipative and stream direction diffusion effects are neglected, as are pressure and thermal diffusion. With these conditions it is shown that for a single reaction occurring, all specie concentrations depend only on a parameter which is a measure of the degree of advancement of the chemical reaction. If all component specific heats are equal, the temperature is shown to depend on this parameter and a generalized enthalpy function. Solutions for the advancement parameter and generalized enthalpy function are given for the case where the reaction time is long compared to the diffusion time. A fluid undergoing a first-order reaction in a reactor with wall temperature equal to the entering fluid temperature is considered for sample calculations. Possible extensions to the theory are indicated.

T. C. Adamson, Jr., USA

2691. Adler, J., The limits of the eigenvalue of the laminar flame equation in terms of the reaction rate-temperature centroid, *Combustion and Flame* **3**, 3, 389-397, Sept. 1959.

Spalding [*Combustion and Flame* **1**, p. 296, 1957] has presented a convenient method for relating laminar flame speed to the centroid of the reaction rate vs temperature function, when the latter is known. While the reaction rate also depends on local mixture composition, it can be formulated *a priori* in terms of temperature alone in the special case when the Lewis number ($k/D\rho C_p$) is unity. The present study derives upper and lower theoretical bounds to the possible error resulting from the application of Spalding's centroid formula to the above problem. The maximum error is found to be small for flames with high activation energy; for example, when the dimensionless reaction centroid temperature is greater than eight-tenths of the final flame temperature, the maximum error is less than eight per cent.

R. Friedman, USA

2692. Khitrin, L. N., A possible part played by catalytic surface burning in high temperature combustion of gases in a flow (in Russian), Investigations of combustion processes, Moskva, Akad. Nauk SSSR, 1958, 123-124; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 9812.

It was established on the basis of an analytical investigation of the mean equation for combustion that in channels of relatively large diameters ($d \geqslant 15$ mm) the process of combustion in high temperature conditions appears to be mainly a volumetric process; in fine-grained charges (with diameter δ of the grain $\leqslant 5$ mm) the process of combustion (in the same temperature conditions) in the case of catalytically active charges appears to be a surface process. Concrete calculations made by the author show that in the case of the burning of carbon oxide in a duct 15 mm in diameter the process of combustion ends at a distance of 70 cm; in the case of an active charge ($\delta \leqslant 5$ mm) the process ends at a distance of 3-4 cm.

G. A. Varshavskii

Courtesy Referativnyi Zhurnal, USSR

2693. Burrows, M. C., Effect of nozzle convergence length on performance of a heptane-oxygen combustor, NASA TN D-579, 22 pp., Dec. 1960.

The effect of nozzle convergence length on the performance of heptane reacting with gaseous oxygen was evaluated in a nominal 200-pound-thrust uncooled combustor. Varied lengths of the nozzle convergence section between the chamber and throat and various cylindrical-chamber lengths were used to provide different combustor gas velocity profiles. Characteristic velocity as a function of the characteristic length and of the total combustor length was obtained for three lengths of the nozzle convergence section. The study was made with two injectors of different performance characteristics, a single contraction ratio, and one propellant-flow condition.

Experimental results show that total combustor length provided the closest correlation of combustor performance when using short combustor lengths and a relatively low-performance injector. When performance was increased by using a longer combustor length or higher-performance injector, the combustor performance was a function of characteristic length. Comparison of the experimental results with analytical data in the literature showed that the experimental effect of nozzle convergence length expressed as equivalent chamber length was considerably less than the effect predicted analytically.

From author's summary

2694. Solov'ev, V. V., The problem of vibrational combustion in highly stressed combustion chambers (in Russian), *Inzh.-Fiz. Zh.* no. 1, 25-31, 1959; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 9964.

Paper has as its object the analysis of vibrational combustion which has been observed in highly stressed combustion chambers working on pulverized coal and lignite. Results are given. It was demonstrated experimentally that the frequency of the vibrations originating in the combustion chambers is close to the frequency of the natural vibrations of a gaseous column in a tube with one closed end; on this finding a deduction is put forward that the vibration presents in itself acoustic longitudinal vibrations of a column of gas. The presence of pressure fluctuations in the combustion chamber results in the development of disintegration of the fuel mixture and, in consequence, of variations in the liberation of heat. In the case where there is a favorable phase correlationship between the pulsations of heat liberation and of pressure, determinable by the delaying of the firing of the fuel mixture, a stimulation of the system may result. It is shown both theoretically and experimentally that excitation of vibrations in the combustion

chamber corresponds with the coincidence of the vibration phases for heat liberation and pressure. A. B. Ezrokhi

Courtesy Referativnyi Zhurnal, USSR

2695. Denisov, Yu. N., Troshin, Ya. K., and Shchelkin, K. I., Analogy between combustion in detonation waves and in rocket engines (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 6, 79–89, Nov./Dec. 1959.

Paper summarizes authors' studies on Hugoniot curve properties [Troschine, Seventh Symposium (International) on Combustion, N.Y., Acad. Press, p. 789, 1959; AMR **13**(1960), Rev. 1501; *ARS J.* **29**, 10, p. 750 (Russian Suppl., 1959; AMR **13**(1960), Rev. 2539]; spining detonation [Denisov and Trochine, *Dokladî Akad. Nauk SSSR (N.S.)* **125**, p. 110, 1959] and unstable combustions [Shchelkin, *Zh. Exp. Teor. Fiz* **36**, 2, p. 600, 1959].

An inequality where E is activation energy, T_i temperature, p_i pressure in the front of the ignition plane, p_b pressure of burned gases

$$\frac{E}{RT_i}\left[1-\left(\frac{P_b}{P_i}\right)^{\frac{\gamma-1}{\gamma}}\right] \gtrsim 1 \qquad [8]$$

is used to define the conditions in which: (1) the ignition plane inside the detonation wave becomes unstable, and the spin appears; (2) a high-frequency combustion instability is able to set up in the liquid-rocket chamber.

Authors believe that arguments in favor of analyzed thermodynamic analogy remain valid even if the reaction zone model used to establish [8] is not exactly true as is the case for a turbulent combustion in liquid rocket chamber.

N. Manson, France

2696. Berry, V. J., Jr., and Parrish, D. R., A theoretical analysis of heat flow in reverse combustion, *Trans. Amer. Inst. Min. Metall. Engrs.* **219**, 124–131, 1960.

Reverse combustion is one thermal method of recovering hydrocarbons from porous underground formations containing oil or tar. In applying this method, air is introduced via an injection well and the mixture of air and hydrocarbons is ignited in the production well. A combustion zone then recedes toward the injection well, counter-current to the air flow. If the combustion-zone temperature is sufficiently high, the oil or tar in place is distilled and cracked. The hydrocarbon flows as a vapor to the production well and subsequently is condensed at the surface.

Maximum temperature and velocity of movement are the two dependent variables defining the progress of the combustion zone. A theoretical analysis has been made of heat flow in the reverse-combustion process assuming linear flow in a homogeneous system. The differential equations, which include the oxygen-hydrocarbon reaction rate, have been solved numerically. Results indicate that the maximum temperature reached and the combustion-zone velocity both increase with an increase in air-injection rate. Heat loss to surroundings has little effect on the maximum combustion-zone temperature achieved, but it is reflected in a reduced combustion-zone velocity. It is also predicted that an increase in the oxygen-hydrocarbon reaction rate results in a reduction in the maximum temperature reached. The calculated results are in agreement with results from reverse-combustion experiments using samples of a tar sand. From authors' summary

2697. Vulis, L. A., Kashkarov, V. P., and Leont'eva, T. P., An investigation of complex turbulent jet flows (in Russian), Investigations on the physical bases of the working processes in furnaces and ovens, Alma-Ata, Akad. Nauk KazSSR, 1957, 86–111; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5245.

A theoretical investigation is made of a flow formed by parallel turbulent jets. The following problems for an incompressible liquid are examined: (1) the mixing of oncoming or following plane unbounded homogeneous flows; (2) the propagation of a plane and axially symmetrical jet, from the source in the following or oncoming homogeneous flow; (3) the flow formed by two oncoming jets. It is shown that the solution of the problem regarding the mixing of following or oncoming plane flows had already been obtained with the aid of the method of the layer of finite thickness and also of the method of the asymptotic layer. An attempt was made to generalize these problems to embrace a class of oncoming flows when, with the help of two models of turbulent motion, it was found that (a) the turbulent viscosity was constant, thus corresponding to a laminar flow; (b) the turbulent viscosity was proportional to the differences of velocities and coordinate. The problem was then solved, by means of the method of the layer of finite thickness of the case of an oncoming motion, and a calculation is carried out for the distribution of the temperature (or the concentration of the admixtures) for following and oncoming flows of an incompressible liquid. When solving the problem of a jet propagating in an oncoming or following flow, an approximate method of superposition is used and computations are made for a series of cases. Complex flows formed by an axially symmetrical jet and an oncoming or following homogeneous flow are investigated experimentally. Values were obtained for the empirical constant of turbulence for such cases. The relation is established of the length of the zone of counter currents to the velocity of the jet and the oncoming flow and also to the diameter of the jet's nozzle. An approximate picture is drawn to show the flow formed by two oncoming jets. Tests are carried out, the results of which were compared with the calculation data.

Yu. F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

2698. Vlasov, K. P., On the relation between the values of the flame temperature measured by optical and other methods (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk (Energ. i Avtomat.)* no. 3, 100–103, 1959. (Translation by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., Pap. V-151, 6 pp.)

A number of investigations have shown that optical methods yield elevated values of the temperature in the turbulent flame combustion zone as compared with other methods. A previous explanation of this phenomenon has shown that optical methods yield elevated values of the temperature in comparison with the time averaged values when temperature oscillations are present at a point in time.

In this work author analyzes the use of optical methods (methods of inverting spectral lines and infrared pyrometry) to measure the turbulent flame temperature. It appears to be possible to find the relation between the average thermodynamic temperature and the temperatures according to the data of optical methods.

The mean-square value of the pulsation temperature, caused by inadequate micro-mixing of fuel and air which often occurs in conventional technical apparatus, can also be computed by means of the values of the burn-up temperature measured by the method of inverting spectral lines. From author's summary

Book—2699. Summerfield, M., edited by, Solid propellant rocket research; Progress in astronautics and rocketry, Vol. 1, New York, Academic Press, 1960, xix + 692 pp. $6.50. (Revs. 2699–2725)

Most of the book deals with the combustion of solid propellants. The particular topics singled out for attention are: Steady-state burning of composite propellants, combustion of metals, unstable burning in solid propellant rockets, and ignition. In addition, the book includes a section on mechanical properties of solid propelland grains, essentially as a subject in its own right, but partly for

its practical connection with internal ballistic design and hence with combustion. Many topics in solid propellant research are not represented at all—thermochemistry of propellants, chemical kinetics of propellent gases, nozzle design, heat transfer, etc. It was simply not possible to do the whole job in one book or in one symposium.

The papers chosen for this book were selected largely for their orientation toward scientific understanding of basic phenomena, although several papers on the engineering aspects of a topic were also included in order to provide the technical background of the problem on which the research papers are centered.

In each topical area covered, this book brings together in one place for the first time some of the most significant lines of current research. Thus, the reader's attention is directed particularly to the papers on unstable burning, both theoretical and experimental. In the theoretical papers, diverse treatments are presented for the basic mechanism of interaction between a small-amplitude, acoustic-type oscillation in the gas-filled chamber of a rocket motor and the flame zone at the surface of the burning propellant. The question of stability or instability of the oscillation depends on the nature of this interaction and, consequently, on the structure of the thin flame zone.

The question of the structure of the thin flame zone is important not only in the treatment of unstable burning but, of course, in the steady-state burning-rate field as well. In the section on steady-state burning mechanisms, three different approaches are offered to the analysis of the factors that control the burning of a composite-type solid propellant. In these papers, three physical models are developed for the burning process, one based on a granular diffusion flame, a second on a two-dimensional diffusion flame, and a third on the proposition that the ammonium perchlorate decomposition flame dominates the combustion process.

An intriguing aspect of the combustion of a solid propellant is the influence on its burning properties of minor percentages of powdered metal incorporated in the propellant, particularly the interaction of the propellant flame with gas-dynamic oscillations in the combustion chamber. Some novel researches on the mechanism of burning of metals and the rates of burning are described in a group of five papers in this volume.

The ignition process of a solid propellant is an interesting example of flame physics with important practical applications. The three papers on this subject deal with the basic question of the site of the first flame, whether it occurs in the gas phase or in the solid phase, and the processes that lead to this initial flame. Depending on the conclusions that will ultimately emerge from these studies, it will be possible to predict, on the basis of fundamental principles, the ignitability of a particular propellant and the igniting capability of a particular ignition system.

The section on mechanical properties deals with the vital problem of calculating the strain distribution in solid propellant grains under the influence of internal pressure with various conditions of restraint or under the influence of temperature gradients. A complicating aspect of the problem is that a solid propellant is a peculiar viscoelastic medium, and not a perfectly elastic solid, thereby obscuring to a great degree the criterion for ultimate failure of a grain. This is a subject of great practical importance. The mechanical properties of the solid propellant grain, particularly its acoustic properties, are pertinent also to the prediction of combustion instability, as brought out in one of the papers in the theoretical instability section.

The contributions in this volume, collected as a group, will undoubtedly serve to stimulate further research in these subjects. Although it is an essential limitation of this kind of collection that it cannot provide total coverage of a subject, an attempt was made to supply in each paper the important references that would enable the reader to explore more completely the area of his interest.

From Preface

2700. Boyd, A. B., Burkes, W. M., and Medford, J. E., Grain design and development problems, for very large rocket motors, 3–31.

2701. Freudenthal, A. M., and Henry, L. A., On Poisson's ratio in linear visco-elastic propellants, 33–66.

2702. Williams, M. L., Mechanical properties and the design of solid propellant motors, 67–100.

2703. Au, N. N., A method of strength analysis of solid propellant rocket grains, 101–120.

2704. Vandenkerckhove, J., and Lampens, G., Stress and strain analysis of cylindrical case-bonded grains, 121–138.

2705. Summerfield, M., Sutherland, G. S., Webb, M. J., Taback, H. J., and Hall, K. P., Burning mechanism of ammonium perchlorate propellants, 141–182.

2706. Blair, D. W., Bastress, E. K., Hermance, C. E., Hall, K. P., and Summerfield, M., Some research problems in the steady-state burning of composite solid propellants, 183–206.

2707. Nachbar, W., A theoretical study of the burning of a solid propellant sandwich, 207–226.

2708. Chaiken, R. F., and Andersen, W. H., The role of binder in composite propellant combustion, 227–249.

2709. Glassman, I., Combustion of metals—physical considerations, 253–269.

2710. Gordon, D. A., Combustion characteristics of metal particles, 271–278.

2711. Talley, C. P., The combustion of elemental boron, 279–285.

2712. Wood, W. A., Metal combustion in deflagrating propellant, 287–291.

2713. McClure, F. T., Hart, R. W., and Bird, J. F., Solid propellant rocket motors as acoustic oscillators, 295–358.

2714. Shinnar, R., and Dishon, M., Heat transfer stability analysis of solid propellant rocket motors, 359–373.

2715. Smith, A. G., A theory of oscillatory burning of solid propellants assuming a constant surface temperature, 375–391.

2716. Cheng, S.-I., Combustion instability in solid rockets using propellants with reactive additives, 393–422.

2717. Hart, R. W., Bird, J. F., and McClure, F. T., The influence of erosive burning on acoustic instability in solid propellant rocket motors, 423–451.

2718. Brownlee, W. G., and Marble, F. E., An experimental investigation of unstable combustion in solid propellant rocket motors, 455–494.

2719. Landsbaum, E. M., Kuby, W. C., and Spaid, F. W., Experimental investigations of unstable burning in solid propellant rocket motors, 495–525.

2720. Angelus, T. A., Unstable burning phenomenon in double-base propellants, 527–559.

2721. Price, E. W., Review of experimental research on combustion instability of solid propellants, 561–602.

2722. Wall, R. H., Resonant burning of solid propellants: Review of causes, cures and effects, 603–619.

2723. McAlevy, R. F., III, Cowan, P. L., and Summerfield, M., The mechanism of ignition of composite solid propellants by hot gases, 623–652.

2724. Baer, A. D., Ryan, N. W., and Salt, D. L., Propellant ignition by high convective heat fluxes, 653–672.

2725. Beyer, R. B., and Fishman, N., Solid propellant ignition studies with high flux radiant energy as a thermal source, 673–692.

End of Symposium

Prime Movers and Propulsion Devices

(See Revs. 2335, 2533, 2677, 2695, 2702, 2713, 2714, 2716, 2718, 2719)

Magneto-fluid-dynamics

(See also Revs. 2801, 2803, 2804, 2806)

2726. Krzywoblocki, M. Z. v., and Nutant, J., On the similarity rule in magneto-gas-dynamics (in English), *Acta Phys. Austriaca* **13**, 1, 1–18, 1960.

Steady flow, in an electromagnetic field, of a perfect gas with zero viscosity, zero thermal conductivity, and non-zero heat additions is examined. Using a simplified pressure-density-entropy relation (an extension of the Chaplygin pressure-density relation), the Karman-Tsien similarity rule is extended to include electromagnetic and heat effects. A bibliography listing 114 selected publications on the subject of magneto-fluid-dynamics is attached.

E. L. Knuth, USA

2727. Sakurai, T., Two-dimensional flow of an ideal gas with small electric conductivity past a thin profile, *J. Phys. Soc. Japan* **15**, 2, 326–333, Feb. 1960.

In AMR **12**(1959), Rev. 5255, two-dimensional flow of a gas with high electrical conductivity was considered. Present paper considers the case of small conductivity (e.g. conditions in the ionosphere).

Thin wing expansion technique is used to derive a linearized flow equation, which is solved approximately by expanding in terms of powers of the magnetic Reynolds number (this method is similar to that of Oseen's for viscous flow).

Theory is applied to both subsonic and supersonic flow past a symmetrical profile at zero incidence in an applied uniform magnetic field which is assumed to make a small angle with the uniform flow at infinity. In this case, in subsonic flow, the lift is zero and the drag is positive and proportional to the electric conductivity. In supersonic flow, the (negative) lift is proportional both to the electric conductivity and to the inclination of the magnetic field (for small values of the electric conductivity).

A. W. Babister, Scotland

2728. Oguchi, H., The blunt body viscous layer problem with and without an applied magnetic field, WADD TN 60-57 (Brown Univ., Div. Engng.), 45 pp., Feb. 1960.

The viscous flow in the shock layer about the stagnation region of a sphere in hypersonic flight is considered. An analytic method of solution is presented under the assumption of constant density in the shock layer; the technique is to use the fact that the ratio of the densities ahead of and behind the shock (ε) is small, to apply an appropriate scale transformation in ε and to use a successive approximation scheme in terms of ε. This method applies to this problem both with and without the presence of a magnetic field.

The unknown shock-wave location is found in analytic form to first order in ε. In the nonmagnetic case the shock-wave detachment distance and skin friction for $\varepsilon = 0.1$ are in good agreement with exact numerical calculations made by others.

The magnetic field is a dipole with the center of the sphere as its origin. It is found that for fixed ε and Reynolds number the skin friction decreases and the detachment distance increases with a parameter which is essentially the ratio of magnetic to total pressure.

S. Ostrach, USA

2729. Kanwal, R. P., and Truesdell, C., Electric current and fluid spin created by the passage of a magnetosonic wave (in English), *Arch. Rational Mech. Anal.* **5**, 5, 432–439, July 1960.

The authors arrive at the complete classification of magnetohydrodynamic and sonic waves in a conducting fluid by the simple and elegant method of singular surfaces. It is demonstrated that the relation $\rho[U]w = -B_n[j]$ between the jumps [j] and [w] of the current and vorticity vectors is valid for any singular surface and for both compressible and incompressible media in the absence of dissipative effects. U is the propagation speed of the wave, ρ is the mass density, and B_n is the component of magnetic induction perpendicular to the wave front (MKS units). Several specific references are made to an unpublished report by the second author [C. Truesdell, "Kinematics of singular surfaces and waves," Univ. Wisconsin MRC Rep. 43, (1958)]. Reading of the paper could have been made easier by updating these so as to refer to the "Handbuch der Physik" article containing the same material [C. Truesdell and R. A. Toupin, "The classical field theories," "Handbuch der Physik" 3, Pt. 1 (1960)].

J. W. Butler, USA

2730. Schirmer, H., and Friedrich, J., Thermal conductivity of plasmas (in German), *Z. Phys.* **153**, 5, 563–570, 1959.

The solution of the Boltzmann equation of an arbitrarily ionized plasma of nonuniform temperatures is given. This leads to a specification of the stream density and the heat flow by means of electrons, from which is obtained the conductivity, mobility, diffusion and thermal diffusion of the electrons. All of these transport coefficients are written in terms of appropriate mean free path lengths with an appropriate coupling coefficient which, because of complete agreement of the expression of the transport coefficient for a Lorentz-gas and plasma, are representable for a Lorentz-gas by integrals, for a plasma by determinants.

R. M. Drake, Jr., USA

2731. Cassidy, J. F., Martinek, F., and Ghai, M. L., A high temperature tunnel using plasma generators, AFOSR TN 60-1412 (Gen. Elect. Co., Flight Propulsion Lab. Dept., Cincinnati), 43 pp., Dec. 1960.

Paper describes experimental investigations carried out during the past two years in developing a high-temperature heat-transfer tunnel using a plasma generator.

Conventional and continuously operating wind tunnels have been limited to temperatures below 3500 °F. The technological develop-

ment resulting in a wind tunnel capable of continuous operation at temperatures as high as 8000°F is presented.

The discharge flow of a gas-stabilized plasma generator was investigated with thermocouple probes and photographic techniques such as schlieren systems, shadowgraphs and high-speed photography. The results indicated that the flow was unsteady and nonuniform even though plenum chambers and a gas-stabilizing tunnel were used. Advances in arc generation technology eliminated the objectionable flow characteristics and satisfactory temperature and velocity profiles were obtained.

Development of high-temperature sensing instrumentation was accomplished by advancing the capabilities of refractory thermocouples where only wire calibrations had previously been known. A probe system which will determine the temperature and velocity profiles in a gas stream at temperatures of 5100°F is presented. Also, various techniques and results derived for calibrating complete probes is presented and discussed.

From authors' summary

2732. Wiese, W., Berg, H. F., and Griem, H. R., Measurements of temperatures and densities in shock-heated hydrogen and helium plasmas, *Phys. Rev. (2),* **120,** 4, 1079-1085, Nov. 1960.

Temperatures and densities in plasmas produced by strong magnetically driven shock waves in a "*T*" tube were measured spectroscopically. Local thermal equilibrium exists within the experimental accuracy for the conditions of this experiment. In both gases, the measured temperatures and densities are in disagreement with the values expected from the Rankine-Hugoniot relations, unless it is assumed that the conditions in the ambient gas are drastically affected by the initial discharge. Consistency between experiment and shock theory is achieved by considering magnetic pressure and dissociation and excitation of the ambient gas by ultraviolet radiation from the discharge.

From authors' summary

Aeroelasticity

(See also Revs. 2339, 2614)

2733. Chopin, S., Flutter calculations when certain modes have almost identical frequencies, without their generalized masses being the same (in French), *Rech. Aéro.* no. 76, 49-52, May/June 1960.

In ground resonance tests we sometimes find two modes having neighboring frequencies, and there is some doubt as to which of these modes should be included in a flutter analysis. This report details the systematic procedure to be followed to ensure that the lowest critical flutter speed is obtained.

Two simple cases are considered: (1) two identical modes with neighboring frequencies and (2) two distinct modes with very close frequencies. The flutter calculation is performed with two and three degrees of freedom.

It is shown that, to obtain the lowest critical speed, the form having the smallest generalized mass is to be used. A two-degree-of-freedom calculation should also be made between these neighboring modes; if flutter is found in this case, it will be "explosive."

A. W. Babister, Scotland

2734. Romanovskii, Iu. M., and Strelkov, S. P., On the influence of atmospheric turbulence on an airplane with elastic wings for different flight speeds (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 3-10, July/Aug. 1959.

The described method allows for a simple calculation of statistical characteristics of forced oscillations of an elastic wing of an aeroplane under action of atmospheric turbulence. Using this method oscillations with various degrees of freedom can be considered. Increase of degrees of freedom by one unit causes an increase of the order of the system of algebraic equations to be solved by two units. This would require some unimportant changes in the standard programming; time of computation will increase severalfold.

Comparison of statistical characteristics of oscillations of one and the same aeroplane model shows that at sufficiently low frequencies of wing twist in the vicinity of critical flutter speeds, wing twist cannot be neglected and the combined bending-torsion oscillations of the wing must be taken into consideration.

From authors' summary by J. Solvey, Australia

2735. Zisfein, M. B., and D'Ewart, B. B., A new approach to safe flight flutter testing, AFOSR TN 60-1027 (Bell Aerosystems Co. Rep. 9015-19-002), 41 pp., Sept. 1960.

This report presents a very brief historical background, a discussion of the basic principles of "jet mass" and its effect on flutter, and a description of the design details of two jet mass prototypes and a wind-tunnel flutter model. Subsequent sections of this report describe the laboratory and wind-tunnel tests on the prototype jet mass systems. The report ends with a statement of conclusions including recommendations for future jet mass system development.

From authors' summary

Aeronautics

(See also Revs. 2345, 2349, 2464, 2553, 2584, 2726, 2753)

2736. Lighthill, M. J., Mathematics and aeronautics (The forty-eighth Wilbur Wright memorial lecture), *J. Roy. Aero. Soc.* **64,** 595, 375-394, July 1960.

2737. Ridland, D. M., The longitudinal frequency response to elevator of an aircraft over the short period frequency range, Aero. Res. Counc. Lond. Curr. Pap. 476, 54 pp., 1960.

Using the methods of systems analysis common in electrical engineering the author develops the transfer functions for velocity in flight direction, velocity normal to flight direction, rate of pitch and normal acceleration depending on elevator deflection. These transfer functions have four poles and have zeros. Simplification of the system of fourth order to a second-order system is considered (neglect of phygoid motion) and its applicability is carefully discussed. Examples for three different types of aircraft are given. The formulas derived can be used for estimating aircraft response characteristics or for evaluating measured aircraft responses.

I. Flugge-Lotz, USA

2738. Kosko, E., The telescopic strut as a beam-column, Univ. Toronto, Inst. Aerophys. Rep. 66, 22 pp. + figs., Jan. 1960.

A cantilever strut such as used in shock absorbers for aircraft landing gear is analyzed, taking into account the effect of lateral deflections. The concept of overlapping stiffnesses is applied to the cylinder-piston combination. As an alternative to the method of successive approximation explicit formulas are derived for a number of simple configurations and loads. A diagram is devised in which the effects of strut and support flexibility on the buckling load are combined. A numerical example shows the usefulness of the latter load in determining the bending moments.

From author's summary

2739. Seiff, A., and Wilkins, M. E., Experimental investigation of a hypersonic glider configuration at a Mach number of 6 and at full-scale Reynolds numbers, NASA TN D-341, 69 pp., Jan. 1961.

The aerodynamic characteristics of a hypersonic glider configuration, consisting of a slender ogive cylinder with three highly swept wings, spaced 120° apart, with the wing chord equal to the body length, were investigated experimentally at a Mach number of 6 and at Reynolds numbers from 6 to 16 million. The objectives were to evaluate the theoretical procedures which had been used to estimate the performance of the glider, and also to evaluate the characteristics of the glider itself. A principal question concerned the viscous drag at full-scale Reynolds number, there being a large difference between the total drags for laminar and turbulent boundary layers.

It was found that the procedures which had been applied for estimating minimum drag, drag due to lift, lift curve slope, and center of pressure were generally accurate within 10 per cent. An important exception was the nonlinear contribution to the lift coefficient which had been represented by a Newtonian term. Experimentally, the lift curve was nearly linear within the angle-of-attack range up to 10°. This error affected the estimated lift-drag ratio.

The minimum drag measurements indicated that substantial amounts of turbulent boundary layer were present on all models tested, over a range of surface roughness from 5 microinches maximum to 200 microinches maximum. In fact, the minimum drag coefficients were nearly independent of the surface smoothness and fell between the estimated values for turbulent and laminar boundary layers, but closer to the turbulent value. At the highest test Reynolds numbers and at large angles of attack, there was some indication that the skin friction of the rough models was being increased by the surface roughness. At full-scale Reynolds number, the maximum lift-drag ratio with a leading edge of practical diameter (from the standpoint of leading-edge heating) was 4.0.

The configuration was statically and dynamically stable in pitch and yaw, and the center of pressure was less than 2-per cent length ahead of the centroid of planform area.

A method of analyzing a free-flight time and distance history to define the drag for the case of large in-flight variations in drag due to lift was developed and applied and is described in the report.

From authors' summary

2740. Fust, H. D., Development of seat cushions for gliders in order to prevent spine injuries by shock forces (in German), Dtsch. Versuchsanstalt Luftfahrt. Ber. 139, 20 pp., Oct. 1960.

A theoretical determination of the shock forces as they appear at the pilot's seat of a glider in the course of bumpy or crash-landings is practically impossible. Exact values can only be provided by tests. To avoid spine injuries of passengers in gliders, which are often caused by shocks owing to rough landing, tests have been executed with shock-absorbing crepe materials (PVC). For different types of crepe material (PVC) the dependence of the impact forces on the thickness of the crepe material and the impact velocity was determined.

From author's summary

2741. Tapscott, R. J., and Kelley, H. L., A flight study of the conversion maneuver of a tilt-duct VTOL aircraft, NASA TN D-372, 12 pp., Nov. 1960.

A preliminary study is presented of flight records which reveals the nature of the task of flying a tiltduct vertical-take-off-and-landing aircraft through the conversion maneuver in level flight and hovering under favorable wind conditions.

From authors' summary

2742. MacKay, J. S., and Weber, R. J., Performance charts for multistage rocket boosters, NASA TN D-582, 80 pp., Jan. 1961.

Charts relating the stage propellant fractions are given for two- and three-stage rockets launching payloads into nominal low-altitude circular orbits about the earth. A simple method is described for extending these data to higher orbit or escape missions. Various combinations of stages using RP - liquid-oxygen and hydrogen- liquid-oxygen propellants are considered. However, the results can be generalized with little error to any other propellant combination.

Examples are given to illustrate how the charts may be applied to the preliminary design of booster vehicles.

From authors' summary

2743. Moskowitz, S. E., and Ting, L., A realistic approach to problems of optimum rocket trajectories, AFOSR TR 60-1342 (Polyt. Inst. Brooklyn, Dept. Aerospace Engng. Appl. Mech., PIBAL Rep. no. 625), 11 pp., Oct. 1960.

Method due to Ting [*Aerospace Engng.* **20,** no. 1] is discussed for title problem and expedient approximations for case of minimum flight time or maximum altitude are discussed.

S. H. Maslen, USA

2744. Vasarhelyi, B., Glossary of naviagtion aeronautics and transport of small particles in pipelines, [Kozlekedesury Vol. II: Hajozas, repules, posta es csovezetekes szallitas] in Hungarian with English, German, and Russian equivalent, Vol. 2, Muszaki ertelmezo, szotar 8 Budapest, Terra, 1960, 174 pp. 45 Ft.

Astronautics

(See also Revs. 2345, 2413, 2796)

2745. Ewart, D. G., On the motion of a particle about an oblate spheroid, *J. Brit. Interplanetary Soc.* **17,** 6, 162-168, Nov./Dec. 1959.

The motion of a particle about an oblate spheroid in vacuo under the influence of gravitational forces alone is considered, and two methods of solution are presented. The first is obtained by direct attack on the differential equations of motion and is akin to solutions presented by King-Hele [*Proc. Roy. Soc. (A)* **247,** p. 49, 1958] and by Robertson [*J. Franklin Inst.* **264,** 181-269, 1957]. The second is by variation of elements and yields solutions in a very simple manner. Although presented as a first-order theory, it could be extended to higher orders of the constants of the Earth's potential if necessary.

From author's summary by D. C. Leigh, USA

2746. Luidens, R. W., Approximate analysis of atmospheric entry corridors and angles, NASA TN D-590, 42 pp., Jan. 1961.

A simple closed-form approximate solution is developed for corridor depths and entry angles as a function of maximum g load, initial entry velocity, and configuration lift-drag ratio, for vehicles operating at constant angle of attack and modulated angle of attack. The vehicle design and mode of operation that result in the deepest corridors are determined, and the effects of hot-gas radiation and a limiting Reynolds number on corridor depth are discussed.

From author's summary

2747. Kuebler, M. E., Gyroscopic motion of an unsymmetrical satellite under no external forces, NASA TN D-596, 30 pp., Dec. 1960.

This report gives the results of an investigation on the transition from spin about the axis of minimum moment of inertia to spin about the axis of maximum moment of inertia by dissipation of internal mechanical energy. A mathematical discussion, together with charts and diagrams, shows that angular velocities and nutation angle are dependent on the energy and symmetry factors. The low stability of rotation about the axis of maximum moment of inertia, when this inertia is only slightly greater than the mean moment of inertia, is shown.

From author's summary

2748. Grant, F. C., Modulated entry, NASA TN D-452, 19 pp., Aug. 1960.

The technique of modulation, or variable coefficients, is discussed and the analytical formulation is reviewed. Representative numerical results of the use of modulation are shown for the lifting and nonlifting cases. These results include the effects of modulation on peak acceleration, entry corridor, and heat absorption. Results are given for entry at satellite speed and escape speed.

From author's summary by F. R. Marsicano, Argentina

2749. Bennett, F. V., Coleman, T. L., and Houbolt, J. C., Determination of the required number of randomly spaced communication satellites, NASA TN D-619, 29 pp., Jan. 1961.

An investigation for determining the minimum number of passive satellites required to provide given percentages of communication time between any two ground stations is presented along with a sample application. The study is limited to the geometrical and probability aspects of the problem. The sample application is for an assumed transatlantic communication link. The satellites are considered to be in circular, randomly spaced orbits with fixed inclination angles and altitudes. The altitudes considered range from 1000 to 5000 statute miles.

From authors' summary

2750. Huang, S.-S., Some dynamical properties of the natural and artificial satellites, NASA TN D-502, 6 pp., Sept. 1960.

Some qualitative properties of the natural and artificial satellites in the solar system that can be understood in terms of the restricted three-body problem are discussed. Three problems are considered: The satellite system of Jupiter; the Trojan group of asteroids; and the behavior of artificial satellites in the earth-moon-sun system.

From author's summary

2751. Grant, F. C., Analysis of low-acceleration lifting entry from escape speed, NASA TN D-249, 21 pp., June 1960.

Previous papers have shown that lift re-entry under suitably restricted loads may be programmed; that assumed constant drag coefficient is conservative; that further optimization under variation of drag coefficient with lift coefficient is available by restricting the lift modulation to lower lift-drag ratio on either the high- or low-drag sides of the maximum L/D. The present paper treats the general advantage to be found on the high-drag side of maximum L/D. It is shown that the ratio of maximum lift coefficient to minimum drag coefficient is a principal parameter. The simplifying assumptions are constant speed pull-up, exponential density altitude. Only a first pull-up is treated.

M. G. Scherberg, USA

2752. Cubbage, J. M., and Andrews, E. H., Jr., Measured base pressures on several twin rocket-nozzle configurations at Mach numbers of 0.6 to 1.4 with effects due to nozzle canting and stabilizing fins, NASA TN D-544, 19 pp., Nov. 1960.

An experimental investigation has been conducted at Mach numbers of 0.6 to 1.4 to determine the base pressures on several cylindrical afterbody configurations having two propulsive nozzles and to determine the effect on base pressure of stabilizing fins and the canting outward of the propulsive nozzles. Nozzle design Mach numbers of 2.0 and 3.43 were employed in this investigation and cold air at total pressures up to 120 times the free-stream static pressure was used to simulate nozzle flow. The results show that canting the nozzles outward 11° was effective in increasing base pressures at supersonic speeds and that stabilizing fins caused a decrease in base pressure. The magnitudes of base pressure coefficients obtained in this investigation were consistent with those obtained on similar configurations in previous jet-effect investigations.

From authors' summary

2753. Leonard, R. W., Brooks, G. W., and McComb, H. G., Jr., Structural considerations of inflatable reentry vehicles, NASA TN D-457, 23 pp., Sept. 1960.

Some problems of structural analysis of an inflatable reentry glider are investigated. Structures of woven fabric of high-temperature-resistant metal wires are considered, having suitable temperature-resistant coatings. Two basic structural types are presented: the inflated circular cylinder and the inflated plate; the latter being either of the tubular multiweb construction or of the "airmat" construction.

The analysis deals with the buckling and collapse loads of the structures, the deflection of the wings, the tension and shear properties of the fabrics, and the vibration frequencies. A linear theory for inflated "airmat" rectangular plates of constant depth is included, utilizing the principle of minimum potential energy to derive the differential equations and boundary conditions for deflection; this can also be extended to vibration and flutter calculations.

Experiments were performed and their results compared with the theory. The linear theory seems to yield fairly accurate results, in spite of nonlinearities which characterize the mechanical properties of fabric materials.

D. Abir, Israel

2754. Baker, R. M. L., Jr., Westrom, G. B., Hilton, C. G., Gersten, R. H., Arsenault, J. L., and Browne, E. J., Efficient precision orbit computation techniques, *ARS J.* **30**, 8, 740-747, Aug. 1960.

Paper compares the computational efficiency of three numerical methods of orbit and trajectory integration. These were the so-called Cowell method, which simply integrates the total acceleration given by the equations of motion in Cartesian coordinates, the Encke method, which integrates the difference between the total accelerations given by some appropriate reference orbit, and a method of variation of parameters developed by S. Herrick which essentially successively adjusts a set of parameters identifying a changing local reference orbit. Comparisons were made on a ballistic lunar trajectory with perturbations due to the 2nd and 4th harmonics of the earth's field and to the lunar and solar attractions, on a low thrust trajectory, and on a trajectory subject to a corrective maneuver with a thrust high compared to gravity applied some distance from the earth.

Authors conclude that Encke's method is preferable for the ballistic lunar trajectory, variation of parameters for the low thrust trajectory, and the Cowell method in the high thrust case. Although the functional evaluation in the Cowell method is simpler than in the others, its computational inefficiency in the first two cases is attributed to the excessive number of steps required and consequent accumulation of rounding error. Since the paper indicates that a modified Runge-Kutta method was used in the numerical integration, this reviewer opines that the disadvantage of the Cowell method would not have been so great had other numerical integrating methods been used. For example, a high-order Gauss formula (usually encountered in the Cowell method) with prediction and one correction and automatic step size control (staying within range of numerical stability) would permit longer steps with resultant greater improvement for the Cowell method than for the others, although perhaps not enough to make it the best method in the first two cases indicated.

There are several vague and several questionable statements in the paper; e.g., the truncation error is not identified as local or global, nor is its order in the power of the step size given, rounding and truncation errors are presumed to have a Gaussian distribution about zero. Accumulated rounding errors is probably intended. Truncation errors rarely have zero means and, moreover, can scarcely be analyzed statistically.

The absence of detail in the techniques is overcome by the ample bibliography.

M. L. Juncosa, USA

2755. Baker, R. M. L., Jr., Three-dimensional drag perturbation technique, *ARS J.* **30**, 8, 748–753, Aug. 1960.

Author extends to the three-dimensional case the equations of a two-dimensional variation-of-parameters technique given in an earlier paper of his [AMR **13** (1960), Rev. 3125]. These equations are designed for a re-entry trajectory with effects of earth's asphericity and perturbations such as those due to atmospheric rotation, ablation, cross winds, lift, and even transitional drag. Although the method is most efficient, as expected, for high mass-to-area ratios, it is asserted that even for low mass-to-area ratios it is superior to integration of total accelerations.

M. L. Juncosa, USA

2756. Remondiere, A., Missile stabilization through jet flap (in French), *Rech. Aéro.* no. 75, 45–52, Mar./Apr. 1960.

2757. Baker, R. M. L., Jr., and Makemson, Maud W., Fundamentals of astrodynamics, AFOSR TN 59-1045 (Univ. California, Los Angeles, Astrodynamical Rep. 6), 336 pp. Sept. 1959.

With increasing scope and application of astronautics, it has become difficult for the interested engineer to find a single reference summarizing more important aspects of this field. Authors have attempted to compile a handbook serving as an introduction to the history, nomenclature, and practical application of astrodynamics, addressed to the individuals required to work in the field but who need not have deep insight into the building blocks of celestial mechanics, astrophysics, and classical mechanics.

Following brief introduction, partly historical and partly descriptive of simple orbital considerations, a good summary is given of the characteristics of minor planets and comets and their importance to astronomy. The conic sections, coordinate systems, and the appropriate transformation equations are then discussed. This is followed by consideration of the astronomical constants and some discussion of atmospheric structure of our planet.

The principal body of the report is concerned with the more difficult problems of astrodynamics. These are of more concern to the engineer who must deal with the practical limitations of orbital theory and the solution of specific problems. Here are discussed the methods of improving orbit determinations, the N-body problem, special and general perturbations, and non-gravitational and relativistic effects. The closing sections are devoted to observation theory, and the application of astronautics to interplanetary orbits. Again emphasis is placed on practical considerations of importance to the engineer.

The report suffers from attempt to compress too much material into too few words. As a result some continuity is lost and the report is difficult to read in places. The material contained many addenda and errata and careful editing would reveal more. The reviewer missed the beauty and formalism found in the Lagrange and Hamilton equations of motion and regretted the necessity of teaching the subject of astrodynamics to engineers in a short intensive course.

W. W. Berning, USA

2758. Herrick, S., Makemson, Maud W., and Francis, Mary P., Astrodynamical notation and usage, AFOSR TN 60-856 (Univ. Calif., Dept. Astronomy, Astrodynamical Rep. 10), 18 pp., July 1960.

2759. Whipple, E. C., Jr., The ion-trap results in "Exploration of the upper atmosphere with the help of the third Soviet sputnik," NASA TN D-665, 4 pp., Jan. 1961.

In interpreting the ion-trap data obtained from Sputnik III, unexpectedly high electron temperatures were computed by Krassovskii: it was concluded, on the basis of experimental current-voltage characteristics of the collector, that the effective electron temperature at an altitude of 795 km was not less than 15,000 °K, corresponding to a vehicle potential of – 6.4 volts with respect to the plasma. If, however, it is noted that a retarding potential corresponding to the *average* kinetic energy will stop only about half the incident ions, new values of 8800 °K and –3.9 volts, respectively, are obtained.

From author's summary

Ballistics, Explosions

(See Revs. 2323, 2589)

Acoustics

(See also Revs. 2442, 2492, 2556, 2713, 2717)

Book—2760. Lamb, H., The dynamical theory of sound, 2nd ed., New York, Dover Publications, Inc., 1960, viii + 307 pp. $1.50. (Paperbound)

This edition is an unabridged and unaltered republication of the second edition published in 1925.

Ed.

2761. Weyers, P. F. R., Vibration and near-field sound of thin-walled cylinders caused by internal turbulent flow, NASA TN D-430, 58 pp., June 1960.

Measurements of fluctuating pressure are reported outside thin-walled "Mylar" tubes, of one-in. diameter, through which air is flowing under fully developed pipe flow conditions. Care was taken to reduce the internal flow noise, mainly in the frequency range 200 to 6000 c/s, upstream and downstream of the test section. Results are given for thickness of tube from 0.0005 to 0.0021 in., center line velocities from 120 to 350 fps, and at two stations, the first ($r/d = 1/2$) in which a barium titanite transducer is in contact with the skin and the second ($r/d = 3/4$) with a condenser microphone 0.25 in. away.

The spectral density function at $r/d = 1/2$ is higher than measured by Willmarth [NACA TN 4139, (1958)] and possesses one or two sharp peaks at the lower frequencies probably associated with the constraint of the transducer on the thin skin. The high frequency parts of the spectra are however very different from those of Willmarth but this is not commented on by the author.

It is found that the spectral density at zero frequency is finite but this is probably the combined result of extraneous internal flow noise at low frequencies and the skin vibration. The spectra possess similarity, based on U_0 and d at least at the higher frequencies, while the r.m.s. pressure is proportional to the dynamic pressure. Reviewer notes that no dependence on c_f is shown, but this is not surprising in view of the small range of Reynolds numbers used.

At $r/d = 3/4$ the spectral density possesses several sharp peaks associated with the natural modes of the cylinder. Usually the first three modes were dominant although the lowest frequency did not necessarily have the largest amplitude. At higher frequencies the spectra were smooth. At low frequencies the spectral density tended to zero. The mean squared pressure was approximately proportional to U_0^4 while the frequency was proportional to U_0. However no definite similarity parameter involving wall thickness was found and so the effect of thickness on transmission of the pressure fluctuations was not well understood. In spite of the latter, reviewer believes this is an important contribution to this subject, especially for those interested in making related experimental measurements.

G. M. Lilley, England

2762. Riazantsev, Iu. S., On the propagation of weak waves in a continuous medium in the presence of radiant energy transfer, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23**, 4, 1126–1128, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

A linearized system of equations for the propagation of plane waves in a completely ionized ideal gas is given for the case where radiant energy transfer is the only dissipation mechanism. Two particular solutions of the dispersion equation are obtained; that for a weak adiabatic sound wave with attenuation and that for a weak isothermal wave with attenuation. In the latter case the solution is similar to that for sound dispersion by thermal conductivity, with the conduction coefficient replaced by a function of the mass coefficient of absorption of radiant energy.

W. C. Griffith, USA

2763. Mollo-Christensen, E., and Narasimha, R., Sound emission from jets at high subsonic velocities, *J. Fluid Mech.* **8**, 1, 49–60, May 1960.

Paper concerns far field spectra at five angular positions of air jets from nozzles 0.201-in. and 0.375-in. diameter at speeds M = 0.7, 0.88, 0.99. Square root of nondimensional pressure spectra are presented *vs.* Strouhal number based on sound speed ($0 < S \leq 1$), both on linear scales. Reynolds number is suggested to be important similarity parameter and hence far field noise generated in high shear region immediately downstream of nozzle, and all observed features of far field spectra are explainable by sound generator (dipole sheet) in early free-shear layer. Low frequency directional maximum is accounted for by certain wavelengths resonating back and forth across jet, causing increased radiation at $\cos^{-1}[1/(1+M)]$. Shorter wavelengths suffer additional omnidirectional scattering.

A. Powell, USA

2764. von Haselberg, K., and Krautkramer, J., Ultrasonic material testing with improved near sound field (in German), *Acustica* **9**, 5, 359–364, 1959.

Paraxial sound field close to piston vibrating with constant axial velocity contains several maxima and minima, as does directional pattern. Authors find that if axial piston velocity decreases as $\exp(-\rho/R_0)^2$, where ρ is radius along piston and R_0 is a constant, no maxima and minima are present for piston of infinite radius. For piston of radius R, results differ from infinite piston by less than 1 db for $R/R_0 < 1.26$. The desired vibration pattern is obtained by shaping the electrodes properly. Such a radiator is useful in pulse-echo ultrasonic defectoscopy, where the near field irregularities set a limit on inspection for flaws close to the radiator.

V. Salmon, USA

Micromeritics

(See also Revs. 2543, 2579, 2593, 2594, 2684, 2685, 2700, 2710, 2744)

Book—2765. Zenz, F. A., and Othmer, D. F., Fluidization and fluid-particle systems, New York, Reinhold Publishing Corporation, 1960, x + 513 pp. $15.

This substantial treatise covers modern developments in fluids-solids processing, particularly moving-bed techniques as used in catalytic cracking plants in the petroleum industry, and also in other process industries. Inasmuch as these are based on several engineering and scientific principles and disciplines and, on the other hand, find applications in numerous fields, therefore their treatment touches on nearly every major aspect of fluid-particle technology. With fluidization of solids as the central theme, the chapters of this book cover the following main topics: Fluid-particle operations in the process industries; Rheology of powders and physical characteristics of particles; Gravity flow of bulk solids; Flow through fixed beds; Motion of single particles in fluids; Flow through fluidized beds, and bubble phenomena; Fluid and solids circulation in fluidized beds; Pneumatic and hydraulic conveying; Pressure drop and particle distribution in two-phase flow; Particle carry-over from fluidized beds; Heat and mass transfer in particle-fluid systems; Fluid-solids phase diagram.

In view of the ramification of the field, even this large book can cover only the high points of each topic; but this coverage is done very competently, and further and deeper study is facilitated by the extensive bibliography on each topic. It is regretable that the bibliographies do not give the titles of the items; this could have been done with little additional work on the part of the authors, with great increase of usefulness for the reader. The broad coverage of topics is very commendable, because a research worker, investigating some specific field, is made cognizant of other fields, even seemingly quite remote, which may have pertinency to his field of study. The authors performed a valuable service in gathering together the essential information on the subject discipline and organizing it in a systematic order.

K. J. DeJuhasz, USA

2766. Kitago, S., and Kozaki, F., The measurement of relative density of sand, *ASTM Bull.* no. 248, 36–40, Sept. 1960.

A method is given for obtaining maximum and minimum densities which eliminates the need for specially prepared apparatus and highly skilled operators.

From authors' summary

2767. Grishin, M. A., Hydrodynamics of large-grained material in a vortex air flow (in Russian), *Inzhener. Fiz. Zh.* **3**, 6, 82–86, June 1960.

The critical velocity of transition of a fixed bed of coarse-grained material into a boiling state is determined.

The velocity equations of the particles of coarse-grained material have been defined, and the linear dependence between the resistance of coarse-grained material and the change in weight of the material during drying has been established.

From author's summary

2768. Jung, R., The hollow shaft as a conveyor for granular solids (in German), *Forsch. Geb. Ing.-Wes.* **25**, 2, 37–43, 1959.

Paper presents an interesting analytical and experimental investigation on the characteristics of a rotating hollow shaft for the conveyance of granular solids from a bunker. It appears possible to describe the transport process in terms of six dimensionless parameters: (1) the ratio between the transport by volume per unit across sectional area of the hollow shaft and its circumferential speed ωD, (2) a Froude number $\omega^2 D/g$, (3) L/D ratio of the hollow shaft, (4) the particle d/D ratio, (5) the slope of the shaft, and (6) the angle of repose. The simple analytical part, which concerns the evaluation of the transport parameter as a function of slope, L/D and angle of repose for the limiting condition of zero Froude number, yields results in agreement with experiment. Empirical curves are given for the transport parameter as a function of Froude number for sand of 100 to 300 micron. The applicability of the process is restricted to non-sticking materials.

J. O. Hinze, Holland

2769. Yakubov, G. V., The mechanism of isothermal motion of gases in cyclone chambers (in Russian), Proceedings scientific conference of the faculty of mechanism in agriculture, Kazaksk. Agricul. Inst., Alma-Ata, 1958, 97–104; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 4890.

The mechanism is investigated of the isothermal motion of gases in cyclones (centrifugal scrubbers). It is shown that when analyzing the work of a cyclone it is essential to take into account the reserve of potential energy in the flow at the inlet into the cyclone, which in some cases may exceed by many times the reserve of kinetic energy. It is made clear that if the gas at the inlet of the cyclone chamber possesses a large reserve of kinetic energy compared with potential, then the dissipation of

kinetic energy will prevail over its inflow at the expense of conversion of potential energy, and the velocity of the gas along the cyclone's chamber will fall. On the other hand, if the reserve of potential energy of the gas at the inlet to the cyclone is greater than the reserve of kinetic energy, then, at the expense of conversion of potential energy into kinetic energy the velocity of the gas along the cyclone's chamber will increase. A relation is obtained for the static pressure on the walls of the cyclone's chamber in functions of the involution of the flow. It is noted that the easing of the involution results in the lowering of the static pressure at the inlet of the cyclone, while diminution of static pressure at the inlet to the cyclone leads, in turn, to a reduction in the involution of the flow.

Yu. A. Lashkov

Courtesy Referativnyi Zhurnal, USSR

2770. Zelinskii, G. S., and Platonov, P. M., The aerodynamics of a layer of granular medium (in Russian), *Dop. Akad. Nauk URSR* no. 2, 178-182, 1958; *Ref. Zb. Mekb.* no. 9, 1959, Rev. 10375.

The resistance coefficient for a current of air passing through a layer of a granular medium is investigated. A formula is derived for the coefficient of resistance holding good for Reynolds numbers $0.1 \leqslant R \leqslant 200$

$$\lambda = \frac{9}{R} + \frac{1}{R^{0.18}} \qquad [1]$$

In that formula

$$\lambda = \Delta p \frac{d}{h} \frac{(1-k)^2}{6\omega k} \frac{2}{qv^2}$$

$$R = \frac{vd}{\nu} \frac{1}{6\omega k}$$

where Δp is the fall of pressure, d the equivalent diameter of the particles, h the thickness of the layer, k the coefficient for the compactness of the packing of the granular medium, ω the coefficient of the form, v the velocity referred to in the live section of the flow, ν and q the viscosity and density of the air. The coefficients in formula [1] are obtained by analysis of the experimental data by the method of the smallest squares with a mean error of $\pm$ 4.9% and a maximum error of $\pm$ 25%. The magnitudes are also ascertained of the coefficient of the form ω for grains of different agricultural crops, wheat, rye, maize, etc. The results of the experiments are not given.

E. M. Minskii

Courtesy Referativnyi Zhurnal, USSR

2771. Rose, A. H., Jr., Stephan, D. G., and Stenburg, R. L., Prevention and control of air pollution by process changes or equipment, Robert A. Taft Sanitary Engng. Center, Air Pollution Engng. Res. & Dev. Unit, Cincinnati, Ohio, SEC TR A58-11, 68 pp., Nov. 1958.

This paper discusses industry-generated atmospheric contaminants, and methods for their reduction. It classifies the airborne contaminants in two broad categories: aerosols and gases. Aerosols are liquid and solid particles carried in suspension in the air; they can be further classified, according to their method of generation, as: (1) dusts, (2) fumes, (3) mists, and (4) sprays; each class can be further classified according to its size range. The paper treats further: mass rate of emission, source concentration, and meteorological influences. Regarding control of effluent discharge paper lists four procedures: (1) reduction of contaminants at point of discharge, (2) changes in raw material, (3) changing the operational technique and modifying the process equipment, and dilution by use of tall smokestacks, and (4) dispersion of source locations through allocation of land usage, i.e., by regulatory and legal means. The procedures (1) and (2) are discussed in greater detail. As means of controlling emission authors consider the following purifying devices: gravity settling chambers, inertial and cyclonic separators, filters, electrostatic precipitators, scrubbers, and control of gaseous contaminants. Among possible process changes they consider changing over to other primary raw material or fuel, vapor recovery, and incineration of combustible wastes. This is an authoritative, up to date, and concise presentation of a problem of ever-growing importance, and of the means for its mitigation. The bibliography of 36 titles lists pertinent items up to 1955.

K. J. DeJuhasz, USA

2772. Litwiniszyn, J., On the process of formation of the mosaic structure in some loose media (in English), *Bull. Acad. Polonaise Sci. (IV)* **8**, 5, 209-217, 1960.

Author gives a stochastic model for the formation of the mosaic structure observed in some loose media. The phenomenon of the appearance of mosaic patterns furnishes suggestive analogies for other phenomena, such as crystal formation, ordering of the structure of polymers, and the so-called micella pattern in coal.

B. Epstein, USA

2773. Kobak, J., and Loveridge, D. J., Single tube sedimentation apparatus for the measurement of particle size distribution, *J. Sci. Instrum.* **37**, 8, 266-269, Aug. 1960.

The equipment described is of the "liquid column with sediment extraction" type which enables dilute suspension, 0.05% solids concentration by volume, to be used. Thus the sedimenting conditions approximate to those required for unhindered settling of the particles. The apparatus is simple in design and does not require any specialized skills in its operation; one operator can easily control two sizings. Two similar sedimentation tubes have been shown to be devoid of individual characteristics and to be capable of giving reproducible results. The results compared well with those obtained in other laboratories using different sedimentation methods.

From authors' summary

2774. Poner, P. A., Some results obtained in an investigation of the formation of sediment deposits in the lower water of installations equipped with a gridded bottom gallery (in Russian), *Izv. Akad. Nauk KazSSR, Ser. Energ.* no. 1 (12), 61-70, 1957; *Ref. Zb. Mekb.* no. 5, 1959, Rev. 5102.

Results are demonstrated of a laboratory experiment on silt deposition on the down-stream side of a dam in relation to the magnitude of the surplus water discharge and to the character of the distribution of the silt along the dam's front. An empirical formula was obtained for the momentary slope of the formed surface of the silt deposits

$$I_H = I_0 + \frac{A\lambda q\tau^m}{1-k},$$

where I_0 is the initial slope of the bed, τ the time taken in the work of the assembly, λ the specific magnitude of the accumulation of silt, q the degree of saturation of the flow by sediment, k the water-collecting coefficient; the constants m and A are experimentally determined (according to the author's data $m = 0.33$, $A =$ 0.0001 to 0.00012). Computations are also given for the critical slope for the purpose of establishing the beginning of the silting-up of the installation. The relation is submitted in the form

$$I_{cr} = I_0 + \frac{\lambda q}{c(1-k)^{3/4}},$$

where C is an empirical multiplicand ($C = 1650$).

When giving his views on the reliability in operation of dams equipped with grid-galleries, the author refers to cases where they have been "buried" by silt and the consequent difficulties in operation, thereby introducing some uncertainty into the matter. There are no factual data of measurements carried out in the field. The laboratory experiments were carried out in terms of a plane problem and could be applied to dams of any type and not only to

dams equipped with grids. In the work under review insufficient use has been made of the literature available on the problem being investigated. M. S. Vyzgo

Courtesy Referativnyi Zhurnal, USSR

2775. Shishchenko, R. I., Hydraulic calculations in drilling work (in Azerb.), *Azerb. Neft. Kh-vo* no. 12, 6–9, 1953; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5056.

A calculation is given for the hydraulic resistance when a clay suspension is moving along pipes. The clay suspension is looked upon as a visco-plastic liquid, characterized by a viscosity η and a boundary stress of shear τ_0. The results are given of the analysis of the author's experiments, from which it is apparent that the resistance coefficient λ (in the d'Arcy-Weisbach formula) is dependent on the Reynolds number and one other parameter

$$A = \frac{D\gamma}{4\tau_0} \quad \text{or} \quad B = \frac{\tau_0}{v^2 q}$$

Instead of two parameters the author uses only one, which he calls Reynolds generalized parameter R_{pl} which is obtained from the ordinary Reynolds number if the so-called effective viscosity η_{eff} is introduced into it instead of viscosity η:

$$\eta_{eff} = \eta + \frac{\tau_0}{(du/dr)_{mean}}$$

It is shown that by the introduction of the parameter R_{pl} a relation is found between λ and R_{pl} which in form is analogous to the relations for a viscous liquid. Yu. M. Shekhtman

Courtesy Referativnyi Zhurnal, USSR

2776. Shishchenko, R. I., and Ibatulov, K. A., The flow of heavy clay emulsions in tubes (in Russian), *Izv. Vyssh. Ucbebn. Zavedenii. Neft'i Gaz* no. 3, 57–62, 1958; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5057.

The apparatus used for the investigation of the hydraulic resistances to the motion of heavy clay emulsions in tubes is described. The following generalized Reynolds parameter was adopted as a criterion for determining the state of the flow in the drilling pipes

$$R^* = \frac{\gamma dv}{g\eta\left(1 + \dfrac{\tau d}{6\eta v}\right)}$$

where γ is the specific weight of the emulsion, d the diameter of the tube, v the mean volumetric velocity, g the acceleration of the force of gravity, η the structural viscosity of the clay suspension, τ the dynamic stress of the shear [see preceding review]. A graph is furnished to show the dependence of the coefficient of hydraulic resistance λ on the magnitude of R^* for clay emulsions in a range of specific weights from 1.10 to 1.73 g/cm^3. For the calculation of the hydraulic resistances when the flow is structural or turbulent the following formulas are proposed, respectively:

$$\lambda = \frac{64}{R^*}, \qquad \lambda = \frac{0.075}{8\sqrt{R^*}}$$

N. I. Malinin

Courtesy Referativnyi Zhurnal, USSR

Porous Media

(See also Rev. 2526)

2777. Prager, S., Diffusion in inhomogeneous media, AFOSR TN 60-187 (Univ. Minn., Chem. Dept. TR-1), 22 pp., Mar. 1960.

Author considers an inhomogeneous medium in which the diffusion coefficient varies from point to point in a random manner. This diffusion coefficient is calculated, using a formal method, by an infinite series involving correlations between diffusion coefficients at n different points. A procedure of the statistical theory of turbulence [AMR **6**, (1953), Rev. 2855] is used for deriving approximate expression for diffusion coefficient involving only two-point correlations. The important case of diffusion through a porous material is treated. Tensorial symbolism is employed. G. Sestini, Italy

2778. Filinov, M. V., On the problem of displacement of a gas by water (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **27**, 54–57, 1960.

Exact, closed form solution is obtained by author for linearized equations of a time-dependent, plane radial flow of water displacing a gas in an infinite porous medium. Difference in viscosities of water and gas is accounted for. Linearized solution gives pressure distribution accurate to 1.5% as compared to numerical solution of exact nonlinear equations.

Analogous problem for two compressible fluids has been considered by N. N. Verigin [*Izv. Akad. Nauk SSSR*, no. 5, 1952].

C. P. Kentzer, USA

2779. Drekov, V. N., On the theory of nonsteady motion of ground water in the presence of infiltration and evaporation (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 29–37, July/Aug. 1959.

Paper investigates ground water flow problems in which infiltration, evaporation and plant transpiration are taken into account. Both an infinitely deep layer as well as a layer of finite depth (bounded from below by an impermeable barrier) are studied. The solutions are obtained by linearizing the boundary conditions, i.e. by assuming that the free water surface (in the ground) is an almost horizontal surface. This allows one to represent the solutions by means of harmonic functions. The final solutions are given in the form of integrals.

From author's summary by A. E. Scheidegger, Canada

2780. Pesikov, E. S., Water yield from alluvial soils (in Russian), *Trudi Tashkentsk. In-ta Inzh. Irrig. i Mekhaniz. S. Kh., Gidrotekhn. Sektsiya* no. 6 (7), 113–121, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10382.

The calculations are examined for an unsteady filtration in a soil mass having vertical sides; the method used is the progressive change in the stationary conditions, when it is assumed that initially the water completely saturates the mass and that subsequently its dehydration proceeds through openings in the sides. The author appears to be in error in thinking that this scheme corresponds to the conditions of work prevailing in an alluvial dam at the time of its erection. The actual problem does not satisfy the conditions of unsteady filtration. In his deductions for the relations the author makes a number of insufficiently justified assumptions; in particular, when determining the discharge by Dupuis' formula he takes into account the presence of the suction portion, which, as is known, is incorrect. Without this assumption the solution of this type of problem in its analogous setting is well known [see, for instance, I. A. Charnyi, "Subterranean hydromechanics," Gostekhizdat, 1948]. V. M. Shestakov

Courtesy Referativnyi Zhurnal, USSR

2781. Hovanessian, S. A., Waterflood calculations for multiple sets of producing wells, *J. Petroleum Technol.* **12**, 8, 65–68 (Tech. Notes), Aug. 1960.

The method of characteristics which reduces the Buckley-Leverett nonlinear, partial differential equation to two first-order, linear differential equations is applied to the solution of a water-

flood recovery problem for multiple lines of producing wells and one line of injection wells. The application of the method is described by a numerical example, and a brief theoretical background is given. From the results of this study, it is concluded that the cumulative water injected and oil produced are the same for single and multiple sets of producing wells.

From author's summary by N. H. Brooks, USA

2782. Kurbanov, A. K., The working oil-bearing strata with gas present (in Russian), *Izv. Vyssh. Ucheb. Zavedenii. Neft'i Gaz* no. 6, 43–50, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10387.

The problem investigated is the determination of the interval of time elapsing from the moment of the beginning of the working of the petroleum deposit to the moment of the break-through of the gas, which forms a gas cone over the petroleum, to the well. A curve is drawn to show the boundary separating the liquid and the gas (water and air) when pumping liquid from the stratum at a constant yield. The calculations were made by means of Muskat's formula. A comparison is made with the results of experiments carried out by the author on a sand model of the stratum. A method is demonstrated for the determination of the duration of the working of the well before the gas bursts through. [I. A. Charnyi, *Doklady Akad. Nauk SSSR (N.S.)* **92**, 1, 17–20, 1953]. Author concludes that, with a steady yield from the well, the amount of petroleum collected up to the break-through of the gas into the well is greatest when the yield is smallest. It follows that the allotment of a large yield at the beginning of the working with a gradual decrease as the working progresses would be an expedient measure. A graph is furnished to show the changes in the maximum permissible yield by time, calculated by the progressive replacement of the stationary conditions, which is compared with the experimental curve. The agreement is satisfactory.

V. K. Kuz'mina
Courtesy Referativnyi Zhurnal, USSR

2783. Borodin, R. V., A method for studying the filtrational properties of alluvial pebble beds of large capacity (in Russian), *Uzb. Geol. Zh.* no. 4, 19–34, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10399.

Author, noticing the filtrational nonhomogeneity of the alluvial gravel beds in the valleys of rivers originating in the hills, which is determined by the character of their formation, proposes to use pumping from a well with an open face, surrounded by cultivation, to determine the coefficients of filtration for the individual layers. An analysis of the data collected from experimental pumping in the valley of the river Angren showed that the linkage between the yield of the well and the fall of water level in it is essentially nonlinear. This nonlinearity is referred by the author to the influence of the well's yield on the radius of influence. A more fruitful line of inquiry, it would seem, would be a study of the influence exerted by the divergence from the linear principle of the filtration in the region adjacent to the well's face.

V. M. Shestakov
Courtesy Referativnyi Zhurnal, USSR

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 2324, 2435, 2516, 2579, 2631, 2759)

Book—2784. Batchelor, G. K., edited by, The scientific papers of G. I. Taylor; Vol. II: Meteorology, oceanography and turbulent flow, New York, Cambridge University Press, 1960, x + 515 pp. $14.50.

This second volume of the collected scientific papers of G. I. Taylor carries the subtitle "Meteorology, Oceanography and Turbulent Flow", but the whole has a homogeneity of outlook and subject which goes beyond that conveyed by the title and is perhaps not expected knowing the versatility of the author. This common subject is the nature and effects of turbulent flow, in the sea or the atmosphere or the laboratory and, by my count, forty of the forty-five papers relate to turbulence and only the five on tidal oscillations deal wholly with nonturbulent flow. Although there is much of interest for meteorologists and oceanographers, this volume may be regarded as an account of the development of the statistical theory of turbulence and the associated ideas that are fundamental to modern studies of turbulent flow. Acknowledging the importance and originality of this work, it is more interesting to trace the origin and development of the central ideas than simply to applaud the achievement.

When reading these papers, some I regret to say for the first time, I was surprised to see how much of the work on turbulence was published either between 1915 and 1919 or between 1935 and 1938. I formed the impression that G. I. Taylor arrived at this understanding of the nature of turbulent flow during the first period, and put it into mathematical form in the second period when advances in experimental techniques had made possible measurements of fluctuations.

Paper 1 in this volume, "Eddy motion in the atmosphere", introduces the mixing-length theory of eddy transport, uses it to describe transport of momentum, heat and humidity, derives the variation of wind velocity and direction with height and, in passing, points out that Rayleigh's criterion for flow stability is inapplicable to channel flow because of the no-slip condition at the walls. The second, a discussion of the Reynolds analogy between heat and momentum transfer, describes the motion in the viscous (or "laminar") sublayer and most of the fundamental concepts of turbulent flow appear in the following papers. Perhaps the most interesting feature is the continual insistence that turbulent motion must be three-dimensional, with its corollaries that vorticity is being produced by continuous extension of vortex-filaments and that the lack of scale effect in turbulent flow depends on a separation in the length-scales of the motions responsible for energy dissipation and for transport of heat and momentum. As far as I can make out, G. I. Taylor has never believed that an adequate description of any kind of turbulent flow could be obtained either by assuming two-dimensional flow or by linearizing the Navier-Stokes equations.

The second period commences with the formulation of the statistical theory of turbulence which has been the model and inspiration for nearly all subsequent investigations of turbulent flow. It is impossible to overrate the importance of this work but, after reading the papers of the first period, the impression persists that the early work contains the bones of the matter and that the theory was constructed explicitly only when the techniques of fluctuation measurement made the construction not merely a mathematical exercise but a tool for the quantitative investigation of the motion and for the detailed verification of the basic concepts. For this purpose the theory has been extremely successful, but it is curious that the basic simplifying assumption of isotropy now appears more as a catalyst than as an essential ingredient in the theory and survives only in the restricted form of local isotropy. If I were asked to say in what respects we are better informed than we were in 1938, I might point rather doubtfully at the imposing but chaotic mass of experimental material, but the only new idea is that the eddies transferring heat and momentum are comparatively stable objects and that randomness and isotropy are characteristic of the dissipative eddies only.

Only two papers of significance in the theory of turbulence seem to have been published outside these periods and one, on turbulent diffusion by continuous movements, is perhaps singular in that no

experimental material is presented. The other, on the vorticity transport theory, is most intriguing in its attitude to the mixing-length theory. It is accepted now that the mixing-length theory is wrong and misleading and that no one would use it except engineers and meteorologists who prefer to have some answer rather than none at all, but the case against it has been overstated. For a corrective, read this paper and notice the care taken to form an acceptable model of the diffusion process. Notice also the extreme caution with which Taylor used the second relation of mixing-length theory which assumes that eddy diffusivity is a function of mean velocity gradient and of position in the flow. In fact, he derives a relation between temperature and velocity in a wake which does not depend on the second relation and which is in much better agreement with recent measurements than the explicit results which do assume the second relation.

One important development which finds no place in these pages is the theory of local isotropy, introduced by Kolmogoroff in 1941 and since then accepted as the proper framework for discussion of the small-scale motion. In some respects, this is a natural extension from the statistical theory and the idea that the motion responsible for eddy transport is not influenced appreciably by the nature of the dissipation process, but the basic assumption of universal equilibrium of the small-eddy motion does not appear to have been anticipated by Taylor and is, I believe, not easily reconciled with his view of the dissipation process as "the formation of very small regions where the vorticity is very high" (p. 465) caused by continued stretching of vortex lines. This view emphasizes the connection between motions on large and small scales, and seems to imply that the independence assumed in the theory of local isotropy is not complete and may not extend to some aspects of the motion. Some evidence that very small regions of high vorticity do exist [Sandborn, *J. Fluid Mech.* **6**, p. 221, 1950; AMR **13**(1960), Rev. 3511] and that the stretching process is persistent [Townsend, *Proc. Roy. Soc.* (*A*) **209**, p. 418, 1951; AMR **5**(1952), Rev. 1498] confirms the connection and indicates that universal equilibrium is not complete. On the other hand, it is difficult to believe that the small eddies of turbulent flow are not in some kind of universal equilibrium with a structure dependent on the rate of energy dissipation and perhaps the length scale of the large eddies. An improved theory of local isotropy which will reconcile our belief in some form of universal equilibrium with an accurate and realistic view of the dissipation process still lies in the future but it is a problem of very great interest.

Some readers of this volume will have other interests than the nature of turbulent flow, and for them I recommend it as a way of watching G. I. Taylor solve complex problems by close combination of theory and observation. Although a reader is denied the characteristic hand-waving (to illustrate extending vortex-filaments, for example), he may notice the clarity of thought, the ability to make an approximate calculation based on inexact measurements and so to produce an unbelievably precise answer, and, of course, the habit of having done the work twenty or more years ago.

A. A. Townsend, England

Courtesy Journal of Fluid Mechanics

2785. Banal, M., Some aspects of recent research on sea waves (in French), *Houille Blanche* **15,** 2, 103-112, Mar./Apr. 1960.

Paper gives a descriptive introduction to current ocean wave research over a broad field. The principal emphasis is on the statistical approach. There are no references.

C. Cox, USA

2786. Gohin, M., Wave spectra in the vicinity of the coast (in French), *Houille Blanche* **15,** 2, 113-121, Mar./Apr. 1960.

After a brief discussion of Tukey's method of spectral analysis, author discusses the possibility that ocean wave spectra, obtained from a coastal location, can be classified in a family which contains relatively few members. The classification is to be carried out by reducing the individual spectra to nondimensional form by use of an effective mean period of the waves and an effective mean height. Author then proposes to establish the connection between weather conditions and members of the family and hence the statistics of wave spectra from corresponding statistics of the weather.

C. Cox, USA

2787. List, R., Aerodynamic hail stones (in German), *ZAMP* **10,** 2, 143-159, Mar. 1959.

Introduction; Means and methods of experimental study; Stages of development of a large hail stone; Aerodynamic forces acting upon a hail stone; The problem of the largest possible hail stone—such are the five sections of the article. The experimental technique used by the author consisted of a simple and small wind tunnel with maximum open-jet velocity up to 25 meters per second, and $Re = 5.1 \times 10^4$. Aerodynamic forces were measured by a very simple balance, and drag coefficients were calculated by usual methods with accuracy within ± 5%.

Section three gives a detailed description of the stages of development of large hail stones of various geometrical shapes and with special references to the structure of their surfaces and drag coefficients. Section four deals with classification of hailstones into major groups. The main characteristics of the groups are: aerodynamic form, state of surface, absolute weight, specific weight, and cross-sectional parameters. Drag coefficients and falling velocities for various types are given for stormwise and antistormwise motions. Then the author compares experimental and theoretical results and finds that the differences between them are rather high. These differences, and theoretical and experimental results individually, are analyzed for various conditions and Reynolds numbers.

The paper makes a good impression and may be recommended to those engaged in weather research and forecasting problems.

G. A. Tokaty and S. Buchanan, England

2788. Vaughan, W. W., Interlevel and intralevel correlations of wind components for six geographical locations, NASA TN D-561, 92 pp., Dec. 1960.

With the advent of vertically rising missiles the need was indicated for a quantitative measure of the relationship between the winds at various altitude levels. Such a relationship may be established by computing the coefficients of correlation between the wind components at different altitude levels as measured by daily upper air observations. These upper air observations are made from a number of geographic locations throughout the world.

This report provides tabulated data on the arithmetic means, standard deviations, and correlations of the meridional (North-South) and zonal (East-West) components of the wind at various altitude levels for six geographic locations. These statistical data were computed for the annual and monthly upper air observations obtained for a period of seven years (1951-1957) at each location. The basic observational data were obtained on punch cards from the National Weather Records Center, Asheville, North Carolina. Author cites reference which describes the data format and preliminary procedures used in arranging the data for this study.

From author's summary

2789. Hollmann, G., Change of sign of the vertical movement of isobaric surfaces on both sides in extreme wind velocity (in German), *Meteorol. Rdsch.* **12,** 5, 137-138, Sept./Oct. 1959.

The relationship between the vertical movement and temperature field on the isobaric surface, where the horizontal wind speed attains an extreme value, was derived. The vertical movement changes its sign when the isobaric and isothermal surfaces do not coincide with one another. Otherwise, the isolines of the zero-

vertical movement coincide with the iostherms of an extreme temperature on the isobaric surface.

The treatment of the case in which the level of an extreme wind speed does not coincide with the isobaric surface will still remain as a further extension of this work.

H. Arakawa, Japan

2790. Belov, P. N., Prognosis of atmospheric pressure with the aid of empirical functions of influence (in Russian), *Meteorol. i. Gidrol.* no. 2, 10–16, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10328.

Some results are given for statistical prognoses of pressure fields at different altitudes in the atmosphere, carried out by means of linear equations for multiple regression; this method of prognosis the author calls "the method of empirical functions of influence," which is in conformity with the terminology proposed by White and Polson [R. M. White, W. C. Polson, *J. Meteor.* **12**, 5, 478–485, 1955]. As the outcome of some concepts regarding the hydrodynamic theory of prediction the author proposes to utilize a predicted equation having the following form

$$\delta P_i = A_0 + \sum_{j=0}^{m}\sum_{k=1}^{m} A_{ijk} H_{k,j} + \sum_{j=1}^{m} B_{ij}(H_{i,j}, H_{i,j-1}) \qquad [1]$$

where δP_i is the change of pressure at the earth's surface or the height of some isobaric surface at the i^{th} point for the following 24 or 36 hours, $H_{k,j}$ is the value of the geopotential of the j^{th} isobaric surface at the k^{th} point, while $(H_{i,j}, H_{j,i-1})$ is the Jacobean of the magnitudes $H_{i,j}$ and $H_{i,j-1}$ determining the transition of the temperature in the layer between the $(j-1)^{\text{th}}$ and j^{th} isobaric surfaces for point i (the presence of nonlinear terms for $H_{k,j}$ in the right-hand side of [1] distinguishes the present study basically from the American work on the subject). The coefficients A_0, A_{ijk} and B_{ij} are determined here by the method of the smallest squares; for this purpose, and using the former data, determinations are made of the empirical values of the mean quadratic values, and of all possible correlation coefficients for all the terms of equation [1]; the condition for the minimum mean square of the predicted error leads to a system of linear equations of the $(nm+n+m+1)^{\text{th}}$ order with $nm+n+m+1$ unknown coefficients A_0, A_{ijk} and B_{ij} (the index i is treated as a fixed index). In actual predictions m was taken to be equal to 2 (sea level pressures 700 mb and 300 mb) and $n = 14$; here the prognosis covered 20 different points of the ETS and for each of these points another 13 stations were selected surrounding the assigned one and spread over distances of the order of 650–750 km apart from each other. For the calculations of the mean quadratic values and of the correlation coefficients a selection was made from 175 days in the winters of 1953–1956; when these calculations were finished the determinations of all the coefficients A_0, A_{ijk} and B_{ij} (for 20 points of the prognosis, for each of which forecasts were given at three altitude levels for periods of 24 and 36 hours ahead) were combined into 120 systems of linear equations each with 45 unknowns. These solutions were calculated on a high-speed computer of the BESM type; finally, after the coefficients had all been determined it was found that the operational prognosis required a comparatively small amount of computational work to be done and this was performed in a very simple fashion on a specially adapted calculating machine of the type called "Weather" (Pogoda). Data are furnished showing the successful nature of the prognoses obtained in Moscow for 175 days in the winters of 1953–55 and for a subsequent period of 89 days in the winters of 1956–1957. An analysis is also carried out of the contribution made by the carry-over of temperature in the separate layers in the change of pressure. The results obtained indicate the prospects for utilizing statistical methods for the prognosis of a baric field.

A. M. Yaglom
Courtesy Referativnyi Zhurnal, USSR

2791. Romov, A. I., Analysis of pressure changes and of vertical motions at different atmospheric levels with consideration for the effect of orography (in Russian), *Trudi Ukr. Nauk-i. Gidrometeorol. In-ta* no. 7, 3–14, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10329.

Determinations are made for the vertical velocity and changes of pressure from the equation for vortexes in a quasigeostrophical approximation, a barometric formula and the equation for the inflow of heat. This is effected with the aid of the correlation

$$\frac{\partial \Delta z}{\partial t} = -m\,\frac{\partial z}{\partial t}$$

[B. D. Uspenskii, *Meteorol. i. Gidrol.* no. 5, 3–8, 1954]. Here z is the height of the isobaric surface, t the time, m a constant magnitude, Δ the plane Laplace operator. For $\tau = qw$ (where w is the vertical velocity, q the density of the air) the following equation is solved

$$p^2\frac{\partial^2\tau}{\partial p^2} - a\tau = F(x, y, p), \qquad a = \frac{mR^2(\gamma_a - \gamma)T}{gl^2} \approx \text{const}$$

with the boundary conditions

$$\tau = 0 \text{ with } p = 0, \quad \tau = q(x, y) \text{ with } p = p_\times(x, y)$$

Here $p_\times$ is the pressure on the Earth's surface, F a function of z, T. An evaluation of the influence of the orography and friction can by made by means of $q(x, y)$. The expression obtained for τ is then utilized when determining $\partial z/\partial t$ from the vortex equation.

The following conclusion is reached as the result of analysis of the solutions obtained: the action of any one of the active factors being investigated (the transition of the vortex, the advective and nonadiabatic inflow of heat, the orographical influence, and so forth) within the limits of the low-lying layer of air produces at the given level in the atmosphere a change in pressure and a vertical component of velocity of identical sign; the active influence of higher-lying layers produces a change of pressure and a vertical velocity at altitudes with different signs.

G. P. Kurbatkin
Courtesy Referativnyi Zhurnal, USSR

2792. Gontarev, N. P., Some results of investigations of gradients in the Neftyanykh Kamnei region (in Russian), *Trudi Gos. Okeanogr. In-ta* no. 36, 128–202, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10330.

Descriptions are furnished of the basic results obtained from experimental investigations of the vertical distribution of the mean values and pulsations of the velocity of the wind, of the temperature and of the humidity of the air above the Caspian (Neftyanye Kamni) carried out in 1954–1955. The observations were made from an oilwell derrick up to 50m above the surface of the sea. The mean velocity of the wind was measured by means of electric contact anemometers, the horizontal pulsations of the wind's velocity with tensometric anemometers of small inertia, the temperature and air humidity with "Termisterovymi" psychrometers. From the observations on the mean velocities and on the air temperature it was ascertained that the influence of the thermal stratification of the air on turbulent exchange in the atmospheric layer next the earth is only in evidence when the wind velocities are weak or moderate (up to 12-15 m/sec). Because of this it is recommended that when wind velocities exceed 15 m/sec the calculations for vertical profiles of the wind should be carried out not by means of the generalized stepped principle of

$$U = U_1\,\frac{z^\varepsilon - z_0{}^\varepsilon}{z_1{}^\varepsilon - z_0{}^\varepsilon}$$

but by utilizing the simpler logarithmic principle

$$U = U_1 \frac{\log_e (z/z_0)}{\log_e (z_1/z_0)}$$

Here ε is the indicator, depending on the stratification of the air, z_0 the parameter of the roughness, U and U_1 the velocities of the wind on the horizons z and z_1. The magnitude of the parameter of roughness decreases with increase in the wind's velocity. The obtained mean value $z_0 = 0.06$ cm proved to be ten times smaller than had been accepted previously for the sea surface. Comparisons of the readings of the wind vane with those of the electric contact and tensometric anemometers showed that at high velocities of the wind the wind vave on an average gave too high values for the velocity. Consequently, when calculating the magnitudes of the velocity pressure of the wind the recommendation is advanced to introduce a correction into the computed velocity obtained from observations on the wind vane. Irregular wind gusts are characterized by means of a coefficient of gustiness k, which is linked up with the amplitudinal characteristic of pulsation of wind velocity β by the correlation

$$\beta = 2(k-1),\; K = \frac{U_{max}}{U_m},\; \beta = \frac{U_{max} - U_{min}}{U_m},$$

where U_{max} and U_{min} are extremal values for the velocity taken for some interval of time within a 10-min interval of time, while U_m is the mean velocity beyond 10 min.

An analysis is given of the dependence of k on different factors. With increase in the height, k decreases approximately in proportion to the logarithm of the height. With increase in the wind velocity, k decreases appreciably up to velocities of 10–12 m/sec and then increases weakly. With stable stratification of the atmosphere, k proved to be somewhat larger than with the unstable. Gauss' principle is adopted for the more detailed description of the structure for the wind flow in the form of

$$f(|k-\bar{k}|) = \frac{1}{\pi(\overline{|k-\bar{k}|})} \exp -\left(\frac{|k-\bar{k}|^2}{\pi(\overline{|k-\bar{k}|})^2}\right)$$

Here $\bar{k}$ is the mean value for k, while $\overline{|k-\bar{k}|}$ is the mean magnitude of the declination $|k-\bar{k}|$. Gauss' principle was found to be wholly applicable to k, computed for intervals of time of less than 10 secs. A calculation was made to show the repeatability and the reliability of different values for k, taken at one second intervals of time and a wind velocity of 34 m/sec at a height of 15 m.

A conclusion was drawn from observations carried out on the humidity of the air to the effect that the vertical gradients of humidity in the region being investigated are not large and therefore cannot exercise much influence on the processes of corrosion. A more important role is filled here by the high relative humidity of the air in the course of the whole year and the perpetual wetting of the installations by seawater. The supplement to the paper contains a large amount of data collected from the experimental observations.

From author's summary

Courtesy Referativnyi Zhurnal, USSR

2793. Glazova, O. P., Determination of the maximum day temperature of the air by means of data obtained from vertical soundings of the atmosphere (in Russian), *Trudi Tsentr. In-ta Prognozov* no. 61, 120–130, 1957; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10332.

A description is given of the portion of the heat contributing to the raising of the temperature in the air layer next to the earth for the Moscow region, for the warm as well as for the cold times of the year, with the sky cloudless or with a very small amount of cloudiness. The author uses not the total radiation but the radiation equilibrium. This procedure is in contrast to the method used by N. I. Bel'skii [*Meteorol. i Gidrol.* no. 9, 1951] where the data for the total radiation in the warm period of the year in weather with small amounts of cloudiness are utilized. Among examples of basic factors responsible for changes of temperature at the earth's surface the following are cited: the inflow of solar radiation, dynamic turbulence and temperature advection. The general changes in the air temperature from sunrise to the moment of reaching the maximum ΔT are presented in the form

$$\Delta T = \Delta T_R + \Delta T_D + \Delta T_A \qquad [1]$$

where ΔT_R is the change of temperature due to the inflow of solar radiation, ΔT_D the change of temperature on account of dynamic turbulence and ΔT_A the temperature change attributable to dynamic advection. The first to be investigated is the role filled by dynamic turbulence, when cases are selected where there was no advection and the radiation balance was equal to zero. In such a case

$$\Delta T = \Delta T_D \qquad [2]$$

The next stage was to establish the link between ($\Delta T = \Delta T_D$) and the magnitude of the thermodynamic gradient of the temperature

$$\gamma d = \frac{T}{g}\left(\frac{\Delta\bar{v}}{\Delta z}\right)^2$$

where T is the temperature, g the acceleration of the forces of gravity, $\Delta\bar{v}/\Delta z$ the vertical gradient of the vector of the wind's velocity. Magnitude ΔT_D proved to be numerically equal to magnitude λd in the first 300 m. The validity of this relation with a permissible error of ± 1% was 80% and with an error of ± 2%–93%.

Then followed a calculation for that part of the radiation balance which is utilized for heating the air. To carry this out cases were selected where there was no advection, that is $\Delta T_A = 0$. The magnitude of the radiation balance in cal/cm^2 was calculated from actinometric observations. The amount of heat expended on heating the air up to the maximum temperature was determined by the Bel'skii method. The radiation balance being known, and also the amount of air required to heat the air to the maximum temperature, with consideration for the calculated value for ΔT_D, it is possible to determine that fraction of the radiation balance which is used to raise the air's temperature. This, expressed in percentages, was 53 for the warm period of the year and 47 for the cold. Divergences from these mean values lead to errors in the determination of magnitude ΔT not exceeding 1 to 2°. Following this plan, knowing the mean radiation balance for a given day as the result of observations over many years, being in possession of the stratification curve and the data derived from pilot-balloon readings for the same period, it is possible to compute the magnitude of ΔT.

E. P. Borisenko

Courtesy Referativnyi Zhurnal, USSR

2794. Vlasenko, G. Ya., Deryagin, B. V., Kudryatseva, N. M., Prokhorov, P. S., Storozhilova, A. I., and Churakov, V. V., The continuous method of investigation of atmospheric particulates (in Russian), Investigations on clouds, precipitations and thundercloud electricity, Leningrad, Gidrometeoizdat, 1957, 185–188; *Ref. Zh. Mekh.* No. 9, 1959, Rev. 10352.

By using the method of continuous ultra-microscopy it is possible to determine not only the numbers of particles per unit of volume but their distribution by particle-size as well. With this object in view an optical discriminator (a photometric wedge) is placed in the condenser of the ultra-microscope which enables the distribution of the particles to be determined by their brightness. A new method is described for the calibration of the wedge; with this method it is possible to obtain graduation curves to show the relation of the dimension of the particles to the location of the wedge. Details are given regarding the continuous method for the study of atmospheric nuclei of condensation. To this end a simple device is worked out for the "manifestation" of condensation nuclei contained in the atmosphere. This device consists of a

humidifying component and of a cooling channel where the vapor actually condenses at nuclei of condensation. The nuclei of condensation, enlarged in this manner are borne away by a current of air, fall into the cassette of the ultra-microscope and are recorded by the observer. The optimum method for working the device was determined experimentally. On the basis of the continuous method of ultra-microscopy it is possible to achieve automization for the computation of aerosol particles or the "manifested" nuclei of condensation. A schematic plan is put forward for an automatic computer with this object in view. A computer of this type carries out the calculations of particles of aerosols of high computing concentrations without dilution.

S. V. Severin
Courtesy Referativnyi Zhurnal, USSR

2795. Gates, D. M., Near infrared atmospheric transmission to solar radiation, *J. Opt. Soc. Amer.* **50,** 12, 1299-1304, Dec. 1960.

Near infrared solar spectrum observations taken on October 15, 1954 with a double-pass Nacl prism spectrometer have been analyzed for transmission coefficients for the "selective" absorption factor and for the "continuum" factor. The analysis was carried out for 59 wavelength positions between 0.872 and 2.537 μ. The monochromatic data fit well the law $^{\circ}nT = c_1(w)^{1/2}$ where w is the amount of water vapor in the optical path. The coefficient c_1 is given as a continuous function of the wavelength. A coefficient of extinction for the "continuum" factor is also given.

From author's summary

2796. Seddon, J. C., Summary of rocket and satellite observations related to the ionosphere, NASA TN D-667, 22 pp., Jan. 1961.

New knowledge relating to the earth's ionosphere in the past three years by rocket and satellite methods is reviewed. Measurements of electron densities up to and above the F_2-maximum, columnar electron densities, electron density gradients, sporadic-E and spread-F are discussed. Other parameters important to the formation of the ionosphere are also briefly discussed. An extensive bibliography on these subjects is given.

From author's summary

International Symposium on Fluid Mechanics in the Ionosphere, edited by R. Bolgiano, Jr., *J. Geophys. Res.* **64,** 12, Dec. 1959. (Revs. 2797-2811)

The purpose of the Symposium was to bring together, on an invitation only basis, selected experts in ionosphere physics and fluid mechanics for the purpose of (a) acquainting the experts in each discipline with the latest knowledge of the other's field; (b) trying to explain some heretofore puzzling ionosphere data; and (c) trying to interest fluid mechanicians in the problems of the ionosphere. The first three days of the meeting were devoted to tutorial sessions. The mornings were devoted to ionosphere physics and the afternoon to fluid mechanics. The following two days were devoted to constructive discussions of the problems and new ideas. The final day was spent summing up the results. Seven principle conclusions were agreed upon as the outcome of the meeting:

(1) turbulence commonly occurs in the ionosphere up to an altitude of at least 100 Km
(2) the viscous dissipation rate is appreciably smaller than previously thought
(3) large scale anisotropic motions are not adequately described by theory customarily applied to laboratory turbulence
(4) predictions of the structure and intensity of small-scale atmospheric turbulence from large-scale motions alone should be made with caution
(5) Earth's magnetic field has negligible direct effect on turbulence
(6) several possible driving mechanisms for large-scale motions exist but they are contrary to evidence from ionosphere scatter transmission and radio meteor data
(7) hydromagnetic effects probably account for a number of ionosphere phenomena.

The proceedings include the pertinent discussions following the presentations and some of these are well worth reading, as many points were clarified in these discussions.

R. J. Mindak, USA

2797. Stewart, R. W., The natural occurrence of turbulence, 2112-2115.

This was the first of the tutorial papers in fluid mechanics given at the ionosphere symposium primarily for the education of the ionosphere physicists. A fundamental phenomenological discussion of turbulence is presented including a discussion of the atmosphere. The paper only briefly mentions the differences of opinion concerning the conceptual formulation of the turbulence problem, although a word of caution is included concerning blind acceptance of Kolmogoroff's similiarity theory of locally isotropic turbulence (especially since Uberoi has found that turbulence is not always locally isotropic). The paper is summarized with the statements that the atmosphere is probably turbulent everywhere except in strong inversion layers and that the spectral behavior predicted by the similarity theory is reliable enough to predict behavior of phenomena depending upon the high wave number part of the spectrum.

R. J. Mindak, USA

2798. Sheppard, P. A., Dynamics of the upper atmosphere, 2116-2121.

This was the second paper presented during the first afternoon fluid-mechanics tutorial session. The structure of the motion and the mean temperature are described and the thermodynamics are briefly discussed for the stratosphere, mesosphere and lower ionosphere. Vertical convection was concluded to be not a factor in causing disturbances of the mean motion. However, slantwise convection may support disturbances by releasing potential energy. Small-scale turbulence is briefly discussed. Gravity waves are mentioned but not discussed.

R. J. Mindak, USA

2799. Corrsin, S., Outline of some topics in homogeneous turbulent flow, 2134-2150.

This was the first paper of the second tutoring session in fluid mechanics. The author pointed out that the paper was intended only for orientation in the homogeneous turbulence problem and no claim for completeness of coverage was made. However, an excellent outline was presented of the turbulence problem and its mathematical and physical difficulties. The pertinent mathematical analyses were treated and the various theories of turbulent energy transfer were considered and compared. This paper is recommended as an excellent short survey of the problem for those not active in the field but possessing a strong mathematical background.

R. J. Mindak, USA

2800. Long, R. R., The motion of fluids with density stratification, 2151-2163.

This was the second paper presented at the second tutorial session on fluid mechanics. Mathematical treatments of various problems in this category are presented together with a discussion of the complicating effects of vorticity. Several tractable solutions are given and exemplified with excellent flow visualization pictures of the particle flows in question. A brief discussion is also given of current research on the use of boundary-layer theory for the solution of the class of problems characterized by the presence of strong velocity concentrations.

R. J. Mindak, USA

2801. Dungey, J. W., Effect of a magnetic field on turbulence in an ionized gas, 2188-2191.

This was the second paper of the third tutorial session in fluid mechanics of turbulence presented at the ionosphere symposium. The problem is formulated (in vector notation) using Maxwell's equations, and the equations of motion for each constituent of the gas. Approximations and idealizations appropriate to the ionosphere were adopted to facilitate solution. A physical picture is given for the generation of irregularities in electron density by shear flow in the neutral air. Expressions for the electric field are worked out. Author claims that given the velocity field, the electron density spectrum can be determined. Some of the approximations and idealizations adopted are as follows:

(a) terms omitted to account for ionization, recombination, dissociation and charge exchange because interest in the paper is in faster processes;

(b) the magnetic field is close to a dipole field;

(c) inductance of any current circuit is small and the displacement current is small;

(d) no negative ions;

(e) one species of positive ions and one species of neutral molecules;

(f) neglect collisions between electrons and positive ions (not valid in "F" layer). R. J. Mindak, USA

2802. Panofsky, H. A., On the structure of turbulence in electrically neutral, hydrostatically stable layers, p. 2195.

This was a short communication presented at the end of the second tutorial session on fluid mechanics of turbulence. Varied evidence of the quasi-horizontal nature of eddies in stable layers, at altitudes from 100 meters to 13 Km, was reported. It was suggested that a whole spectrum of such anisotropic eddies exist. Only a summary of the paper appears in the proceedings.
R. J. Mindak, USA

2803. Howells, I. D., On the spectrum of electron density produced by turbulence in the ionosphere in the presence of a magnetic field, 2198-2199.

This was the third paper given at the third tutorial session on fluid mechanics. It represents an extention of Dungey's work and obtains approximate equations for number density of ionization, under the action of turbulence, diffusion, and a magnetic field in various limiting cases. A principal result is that this mechanism cannot be expected to produce irregularities that are strongly elongated along the magnetic field. A more complete account of the author's work is to be published at a later date.
R. J. Mindak, USA

2804. Hines, C. O., An interpretation of certain ionospheric motions in terms of atmospheric waves, 2210-2211.

This was the second paper presented at the fourth day's session. This session was one of two following the three tutorial days and set aside for constructive discussions of the problems and new ideas. In this short paper, internal atmospheric waves, both gravitational and compressional in nature, were proposed and analyzed briefly. It was shown that the accompanying motions may have a close resemblance to measurements of ionosphere movements. R. J. Mindak, USA

2805. Golitsyn, G. S., On the influence of the magnetic field on the character of turbulence in the ionosphere, 2212-2214.

This was the fourth paper given on the first day devoted to discussion of problems and new ideas, following the three tutorial days. The equations of magnetohydrodynamics were employed to determine the influence of the earth's magnetic field on turbulence at ionosphere heights. It was shown that below 200 Km the presence of the magnetic field is unimportant regarding turbulence, and that above this altitude, where the ratio of turbulence microscale to mean free path is proportioned to particle number density to the 1/4 power, the problem of turbulence on a scale of interest probably does not exist. R. J. Mindak, USA

2806. Dougherty, J. P., Magnetohydrodynamics of the small-scale structure of the E region, 2215-2216.

This was the fifth paper given on the first day devoted to discussions of new ideas and problems. The author disagreed with Martyn's ideas about the behavior of an irregularity of ionization density imbedded in a moving background of constant ionization density, as applied to the ionosphere. It was proposed that any cylindrical irregularity must extend into the E region, and that this fact would seriously alter Martyn's conclusions (see *J. Geophys. Res.* **64**, 2178-2179, 1959). R. J. Mindak, USA

2807. Yih, C.-S., Effect of density variation on fluid flow, 2219-2223.

This was the seventh paper presented at the first session devoted to discussion of problems and new ideas. It was pointed out that inertial and gravitational effects that arise in this type of stably stratified motion can often be taken into account by certain transformations of the dynamic equations which allow one to relate the motion of an analogous motion of a constant density fluid.
R. J. Mindak, USA

2808. Monin, A. S., Turbulence in shear flow with stability, 2224-2225.

This was the last paper presented at the first session devoted to discussion of problems and new ideas. The turbulence energy balance was considered for mean shear flow and varying density stratification. It was suggested that in a stable situation the energy is reduced and the maximum of the spectrum shifts to smaller scales, whereas in an unstable one the reverse is true. These conclusions, although based on empirical evidence, are claimed justifiable theoreticlaly since the large eddies are most affected by the Archimedes forces. R. J. Mindak, USA

2809. Wheelon, A. D., Relation of turbulence theory to ionospheric scatter propagation experiments, 2230-2231.

This was the next to the last paper given at the second day's session devoted to discussion of problems and new ideas. A one and one-quarter page summary of the paper is all that appears in the transactions. However in the complete paper, two turbulent mixing theories were outlined and the consequent radio propagation predictions were noted and compared with experimental results. The first theory was that attributed to Batchelor, Corrsin, and others, while the second was that attributed to Villars, Weisskopf, the author and others. R. J. Mindak, USA

2810. Monin, A. S., On the similarity of turbulence in the presence of a mean vertical temperature gradient, 2196-2197.

This was one of two short communications presented after the second tutorial session on Fluid Mechanics. In consideration of the frequency spectrum of vertical turbulence components, two similarity methods are employed to describe (1) energy and inertia ranges and (b) inertia and dissipation ranges. Author proposes a relation between the two theories since they both hold in the inertia range. Both of the theories agree with measurements made in the author's laboratories and favor a −5/3 law for the spectrum rather than Kraichman's −3/2 law. R. J. Mindak, USA

2811. Bibl, K., and Rawer, K., Traveling disturbances originating in the outer ionosphere, 2232-2238.

This was the last paper presented at the second day devoted to discussion of ideas and problems. A number of ionograms were presented depicting rapid changes in the large-scale structure of

the ionosphere. It was suggested that many of these changes could be interpreted in terms of vertical movements of the gaseous matter (ionized and neutral). R. J. Mindak, USA

End of Symposium

Naval Architecture and Marine Engineering

(See also Revs. 2303, 2491, 2504, 2595, 2603, 2744)

2812. Isay, W. H., Theory of submerged hydrofoils for rolling flow (in German), *Ing.-Arch.* **29**, 3, 160–175, June 1960.

Earlier (P. Kaplan) the title problem was treated by borrowing characteristic data from aerodynamics (solutions valid for the unbounded fluid). Author considers the actual boundary conditions on the profile when establishing the integral equation for the circulation. Assuming that the flow consists of a uniform main part and wavy components the potential is found for a single vortex and therefrom the velocity field around the hydrofoil (fixed and free vortices). For a heaving foil (small amplitudes) the boundary condition is fulfilled in the usual approximate way. From the complicated integral equation for the circulation, the forces and the form of the free surface are calculated, using a finite number of equations or applying the approximate 1/4–3/4-point method, which is strongly recommended. The problem at stake has been solved by Nishiyama by conformal mapping without considering, however, the heaving motion. G. P. Weinblum, Germany

2813. Lang, T. G., Daybell, Dorothy A., and Smith, K. E., Water-tunnel tests of hydrofoils with forced ventilation, NAVORD Rep. 7008 (U. S. Nav. Ord. Test. Sta., China Lake, Calif. TP 2363), 109 pp., Nov. 1959.

Data from water-tunnel tests show the hydrodynamic effects of forcing air through ports in the surface of a hydrofoil as a function of stream velocity, angle of attack, location and shape of the air ports, air-flow rate, and aspect ratio. Measurements include lift, drag, and moment acting on the hydrofoil, pressure distribution, air-flow rate, and cavity pressure.

The forces acting on the hydrofoil change rapidly with increasing air-flow rate until the air cavity extends past the trailing edge, beyond which point little further change is noticed. This steady condition is defined as the "fully vented" region. Typical results show that when the hydrofoil is fully vented by forcing air through a spanwise row of holes near the leading edge, the lift coefficient may change as much as 0.6 from the fully wetted value at zero angle of attack. The ratio of the lift of a hydrofoil with finite aspect ratio to that of a hydrofoil with infinite aspect ratio is approximately the same in fully vented flow as it is in fully wetted flow. The ratio of the lift-coefficient derivative for a fully vented hydrofoil to that for a fully wetted hydrofoil is approximately equal to the ratio of their cross-sectional wetted perimeters. The air cavity does not spring forward of the exhaust port unless the hydrofoil has stalled or excessive cavitation appears behind the leading edge. From authors' summary

2814. Moors, A. J., Resistance of barge tows; model and prototype investigations, U. S. Army Engineer Corps, Ohio River Division, Cincinnati, Ohio (Civil Works Investigations 814 and 835), 124 pp., Aug. 1960.

The purpose of the study reported herein was to investigate channel effects on the resistance of barge tows.

Tests were conducted at 1:36-scale ratio in restricted, shoal, and nonrestricted straight channels. The restricted channels had prototype bottom widths of 125, 225, and 300 ft with 1-on-2 side slopes, while the shoal channels were 540 ft wide with vertical sides. Depths in the restricted and shoal channels varied from 6.5 to 30 ft. The channel dimensions for the nonrestricted-channel tests or "deep-water" tests were 792 ft wide and 342 ft deep, the limiting dimensions of the test-tank cross section. A short series of tests was made in the same channels at a 1:15-scale ratio with the prototype dimensions varied to suit the larger scale. Seven different barges of varying sizes and shapes were tested in flotilla arrangements varying from single-barge to 8-barge tows. All barges in each flotilla were of the same size and loaded to the same draft, except for one series of tests with unequal drafts. Two series of the tests were for integrated and semi-integrated tows. Some of the tests simulated field tests and provided comparisons of model and prototype data.

Comparisons of model and prototype data indicate that speeds predicted from the model tests conform in general with those observed in field tests.

Relations were developed for shoal and restricted channels to indicate the relative effects of variation of channel dimensions on flotilla performance.

An equation was developed to evaluate flotilla performance in deep water. Results obtained from this formula compare reasonably well with results obtained from other model tests of larger tows. From author's summary

2815. Morel, P. G., Computing effective powers and associated coefficients from ship model resistance tests, Nat. Res. Counc. Canada, Mech. Engng. Rep. MB-226, 16 pp. + charts, Sept. 1960.

2816. Greenspon, J. E., A shell-type approach for the vibration and acoustic analysis of ship and submarine hulls, David W. Taylor Mod. Basin Rep. no. 1, 62 pp., May 1960.

Author emphasizes that present report summarizes a preliminary feasibility study on methods he proposed to use to predict vibratory characteristics and acoustic behavior of surface ships and submarines. Ship hull is divided into several structural elements, i.e. shell plate segments, girders, stanchions, internal plate elements and rigid masses attached to hull rigidly or by spring mountings. Lagrange equations are written for each of the generalized coordinates using displacements relative to fixed coordinate axes and rotations around them; rotatory inertia of the shell and bar element is neglected and derivatives are expressed in finite difference form. Acoustic theory is applied for pressure effect of water, e.g. each lateral surface plate element in contact with water is assumed to vibrate like a piston in an infinite rigid cylindrical baffle and mutual or self-impedance calculated by Sherman is introduced into generalized forces. All of potential energy of hull is assumed to be due to membrane action only (in appendix, however, it is shown how bending may also be considered). Setting up equations for computation of forced vibration response due to sinusoidal exciting forces, author obtained a set of equations for theoretical linear displacement of structural elements and rigid masses and their rotations. To illustrate application of this theory, computed results of "Free vibration of cylindrical shell in air" and their comparison with experiments are presented in appendix.
T. Kanazawa, Japan

2817. Crook, Mary C., Summary of reports on vibration surveys issued during 1959, David W. Taylor Mod. Bas. Rep. 1402, 5 pp., Jan. 1960.

2818. Belgaumkar, B. M., Review of the problem of singing propellers, *J. Soc. Naval Architecture Marine Engng.*, Indian Inst. Technol., Kharagpur, special issue on Second Shipbuilding and Shipping Conference, 80–86, Nov. 1959.

2819. Grigor'ev, N. L., Hydraulics—textbook for nautical schools, 3rd revised ed. (in Russian), Moscow, Motor Transport, 1958, 320 pp., + illus. 8 r 30 k; *Ref. Zb. Mekh.* no. 9, 1959, Rev. 10092.

SECTION I. HYDROSTATICS: Chapter 1. Internal forces in liquids and hydrostatic pressure. Chapter 2. The nature of hydrostatic pressure and the reasons for its genesis. Properties of hydrostatic pressure. Chapter 3. The fundamental differential equations used in hydrostatics. Chapter 4. The pressure of a liquid on plane walls of rectangular form. Chapter 5. The action of a liquid on plane figures of arbitrary outline. Chapter 6. The action of a liquid on curvilinear surfaces. Chapter 7. The action of a liquid on a body immersed in it.

SECTION II. HYDRODYNAMICS: Chapter 8. The general character of the motion of a liquid. Chapter 9. Bernouilli's equation. Chapter 10. Differential equations for Euler's theory of hydrodynamics. Chapter 11. The even flow of a liquid. Chapter 12. Local resistances. Chapter 13. The flow of liquid through openings in a thin wall. Chapter 14. Flow through various fitments. Chapter 15. Even motion of liquid in tubes. Chapter 16. Motion of liquid in tubes of dredging installations (soil drainage pipe conduits). Chapter 17. Weirs. Chapter 18. Filtration (motion of water in soils). Chapter 19. Impact of jets. Chapter 20. Irregular motion in open channels. Chapter 21. Wave Motion.

The textbook now appears in its third revised edition and is intended for use by the students of dredging operations in the nautical schools of the Ministry of the marine fleet of the U. S. S. R. The specific conditions of deepening channels are reflected in its pages, relating principally to the section on "Hydrodynamics". In this section some new themes are dealt with: centrifugal pumps, the depth to which suction pipes should be lowered in dredging plant, and so forth. Items of a general hydraulic character are dealt with in greater detail with the inclusion of new subjects, while individual items concerinng hydro-engineering and sanitary engineering are treated in a somewhat abbreviated way.

From author's preface

Courtesy Referativnyi Zhurnal, USSR

Friction, Lubrication and Wear

(See also Rev. 2311)

Book—2820. Awakow, A. A., Physical fundamentals of wear. Theory of cutting tools [Fiziczeskije osnowy; tieorii stojkosti riezuszczich instrumientow], Moskva, Maszgiz, 1960, 307 pp. 12 r 40 k.

This book by the Soviet professor of physics discusses the most important problems of the physical processes of tool edge wear occurring during metal cutting. The author's views are supported by his own investigations.

In the first part author discusses the problem of the dependence of the tool edge strength on changes in cutting conditions, especially on cutting speed. A critical analysis of the problem includes chiefly the results of investigations carried out by Russian and Soviet scientists in the period 1908-1958.

The second part of the book is devoted to an examination of the "physical meaning" of the exponent *m*, worked out from the relation between durability and cutting speed (known as Taylor's formula).

The third part deals with all the various kinds of tool edge wear, ranging from a type of fatigue strength wear to one of abrasive wear and concluding with a type of chemical wear and diffusion-wear. In a survey of recent investigations in this field consideration is given to outstanding works by Russian scientists as well as to the investigations by G. Ostermann ["Beobachtungen über den Verschleiss bei Hartmetallwerkzeugen," Industrie Anzeiger, Nr 11, 1958] and E. M. Merchant ["Production research in metal cutting," *Mech. Engng.* no. 12, 1957]. The final section of the book contains a survey of research methods and results with regard to heat phenomena occurring during metal cutting. An item of particular interest in this section is the analysis of the problem of high-energy cutting, initiated by G. Salomon.

This book will be a valuable contribution to the bibliography on tool wear. It will prove especially useful for readers wishing a quick, exacting, and penetrating comprehension of the whole development of wear theory of cutting tools.

J. Kaczmarek, Poland

2821. Smith, F. W., Lubricant behaviour in concentrated contact; the effect of temperature, Nat. Res. Counc. Canada, Mech. Engng. Rep. MP-17, 13 pp. + figs., Aug. 1960.

Experiments are described on the frictional behavior of a petroleum oil in the contact zone between a steel roller and an aluminum one at 23°C and between steel rollers and between tungsten carbide rollers at 23°C, 100°C and 190°C. The coefficient of sliding friction decreases with increasing temperature. Qualitatively, this is taken to indicate that the frictional force represents the shearing of a thick plastic film of lubricant; quantitative agreement between experiments with steel and with carbide rollers is poor. To explain disaccord with other experiments in which the coefficient of friction increases with increasing temperature, it is proposed that mechanical instability of the lubricant film may be a factor in extreme pressure lubrication. On general physico-chemical grounds, it is suggested that an intermolecular sliding process occurs at a shear plane in typical concentrated contact lubricant films at low temperature and high stresses. The relationship between such shear-plane processes and the Ree-Eyring theory of non-Newtonian viscosity is discussed.

From author's summary

2822. Carter, T. L., A study of some factors affecting rolling-contact fatigue life, NASA TR R-60, 48 pp., 1960.

The rolling-contact fatigue spin rig was used to evaluate the effect on rolling-contact fatigue life of the following factors: stress, forging fiber orientation, lubricant viscosity, lubricant base stock, temperature, dry-powder lubricants, metallurgical structure, and alloy composition. Ball specimens of 1/2 or 9/16-inch diameter were tested at loads producing maximum theoretical Hertz compressive stresses of 600,000 to 750,000 psi. Results reported show that each factor studied had a definite effect on rolling-contact fatigue life.

From author's summary

2823. Weyrauch, V. A., A graphic method for designing internal expanding shoe brakes and internal expanding clutches (in German), *VDI Zeitsbrift* **102**, 15, 601-614, May 1960.

The various basic types of internal expanding shoe brakes and internal expanding clutches can be dealt with by a common dimensional design method. In the first place it must be ascertained whether the contact pressure is to be applied symmetrically or unsymmetrically to the center line of the friction lining. A mathematical and graphical method was evolved to determine the forces occurring, their lines of application, the center point of pressure and the maximum pressures and such brakes and clutches were fitted on various types of machine. Accordingly, the situation can also be dealt with whereby the resultant forces to some extent lift the friction lining from the drum.

From author's summary

2824. Nikitin, A. K., Plane nonlinear problem on steady motion of lubricant between bearing and journal (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 11-21, July/Aug. 1959.

For the case when the liquid fills the entire space between shaft and bearing, an existence and uniqueness theorem is proved for the solution of the nonlinear problem, considering a sufficiently small region occupied by the lubricant. From the theorem follows the convergence of the solution, expanded in a series of positive powers of the Reynolds number, for sufficiently small values of the latter. The solution itself is found in bipolar coordinates. The reaction of the lubricant film on the shaft is determined with an accuracy up to third-order terms with respect to Reynolds numbers, and the effect of the nonlinear inertia terms is demonstrated....

From author's summary by T. Ranov, USA

2825. **Belgaumkar, B. M., Application of electrical analogy to the analysis of hydrodynamic journal bearings,** *J. Sci. Engng. Res., India* **3**, part 2, 385-392, July 1959.

The equations of motion describing the fluid flow in bearings are similar to the equations describing the flow of current in electric circuits or conductors. A brief survey is made of the analogy which exists between electric circuits and the hydrodynamic lubrication system.

R. C. Binder, USA

2826. **Ivanov, N. P., The elimination of mechanical losses in the bearings of model hydro-turbines** (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 198, 79-86, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10155.

A more exact method is proposed for the eradication of losses due to friction in the ball bearings of a shaft in a model of a hydraulic turbine, which enables a better value to be obtained for its hydraulic efficiency. This question became particularly acute when the models in question were designed as aero-models. The power of an air model is considerably less than that of models working on water and the mechanical losses may lower the efficiency by as much as 20%. The problem set was solved by the creation of bearing assemblies in which by means of rotation at identical angular speeds in one direction of the outer and inner rings of the bearings of the turbine shaft, a cessation of movement of the balls is achieved and consequently all phenomena bound up up with that movement disappear. The power developed by the wheel, with the shafts' bearings cut out, can be brake-tested as a whole, when the power indicated can be recorded. A description is given of the construction and of the results of an experimental investigation of a radially-axial hydraulic turbine. The experiment confirmed that the proposed procedure to eliminate mechanical losses enables reliable energetic characteristics to be determined when testing models of hydroturbines on aero testing plant.

V. Kh. Aviants

Courtesy Referativnyi Zhurnal, USSR

2827. **Aref'ev, B. A., and Sivokonenko, I. M., Resistance of a sphere to rolling on a plane (or "the friction of rolling")** (in Russian), *Trudi Leningrad In-ta Aviats. Priborostr.* no. 19, 127-143, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10472.

A semi-empirical approximate evaluation is derived to indicate the resistance forces exerted when a sphere is rolled along a plane, the assumption being that this resistance is conditioned by the elastic tangential stresses evoked in consequence of the cohesiveness of the sphere to the plane over the whole area of the region of elastic contact. A graphical comparison is made of the experimental results with the computational, using the approximate formula.

N. A. Rostovtsev

Courtesy Referativnyi Zhurnal, USSR

2828. **Peeken, H., The influence of subdivision of the bearing surface on the load capacity of lubricating films** (in German), *Ing.-Arch.* **29**, 3, 199-218, June 1960.

The merits of subdividing one of the surfaces of a film-lubricated plain bearing into a series of pads of fixed inclination are discussed, primarily theoretically, and some of the past confusion on this topic is clarified. First, the plane slider bearing, subdivided into multiple pads of infinite width, is analyzed on the usual assumptions of complete oil films and constant viscosity. For the range of pad inclinations most likely to be met in practice, subdivision is shown to lead to a large diminution in load capacity. For larger angles of inclination, subdivision can produce fairly large relative improvements in load capacity, but this is of mainly theoretical significance.

The principal analytical section of the paper is an approximate solution for a single fixed plane slider bearing of finite width, based on the calculus of variations. Maximum load capacity for a given minimum film thickness is shown to occur for approximately square pads operating at film thickness ratios around 2 1/4, results known from other solutions.

The 180° journal bearing with multiple fixed pads of finite width is next examined on the assumption that the earlier plane slider results can be employed. In a comparison with an existing solution for the corresponding plain journal bearing, a superiority of the subdivided bearing is found for width-diameter ratios less than 0.3. At a width-diameter ratio of 0.15 and an eccentricity ratio of 0.7, the use of multiple pads leads to a 74% rise in load capacity.

The paper concludes with a discussion of calculations for narrow journal bearings, including a comment on the relative merits of narrow rolling and sliding bearings.

J. A. Cole, Australia

Letters to the Editor

2829. Re: AMR **13**(1960), Rev. 4298: **Miele, A., and Cappellari, J. O., Jr., Approximate solutions to optimum flight trajectories for a turbojet-powered aircraft,** NASA TN D-152, 33 pp., Sept. 1959.

After further consideration of the paper in question, this reviewer would like to modify his previous statements as follows: The paper contains the only analytical solutions available on the problem of the optimum climbing technique, which is a welcome contribution to the literature. The technique developed in this paper should find useful applications in the performance analysis of aircraft powered by either turbojet or ramjet engines.

C. C. Wan, USA

2830. Re: AMR **13**(1960), Rev. 6619: **Miele, A., Equations of motion of a rocket-powered aircraft,** Boeing Scientific Research Labs., Seattle, Wash., Flight Sciences Lab. Rep. 20, DI-82-0038, 24 pp., Jan. 1960.

After further consideration of the report in question, this reviewer would like to modify his previous statements as follows. Equations of motion of a rocket-powered aircraft are derived in a formal sense to provide an insight to the significance of engineering approximations. A rigorous and new derivation of the equations of the angular momentum for rocket vehicles is also obtained.

C. C. Wan, USA

Books Received for Review

BOOLE, G., Calculus of finite differences, 4th ed. (edited by J. F. Moulton), New York, Chelsea Publishing Co., 1960, xii + 336 pp. $1.39. (Paperbound) ($3.95 clothbound)

DEL VECCHIO, A., Dictionary of mechanical engineering, New York, Philosophical Library, 1961, 346 pp. $6.

HALL, A. S., JR., Kinematics and linkage design, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1961, xi + 162 pp. $8.50.

HAUSNER, H. H., Modern materials; Advances in development and applications, Vol 2, New York, Academic Press, Inc., 1960, xv + 413 pp. $12.50.

HAYWOOD, R. W., edited by, Thermodynamic tables and other data, 2nd ed., New York, Cambridge University Press, 1960, 23 pp. 50 cents. (Paperbound)

JESSOP, H. T., AND HARRIS, F. C., Photoelasticity principles and methods, New York, Dover Publications, Inc., 1960, viii + 184 pp. $2. (Paperbound)

LENCASTRE, A., Manuel D'Hydraulique generale, Paris, Eyrolles, 1961, 411 pp. 38. NF.

LOFFLER, K., Die Berechnung von rotierenden Scheiben und Schalen, Berlin, Springer-Verlag, 1961, viii + 241 pp. DM 42.

MATHESON, J. A. L., AND FRANCIS, A. J., Hyperstatic structures; an introduction to the theory of statically indeterminate structures, Vol 2: Containing worked examples and examples for solution, New York, Academic Press, Inc., 1960, xi + 282 pp. $11.

PUCKETT, A. E., AND RAMO, S., edited by, Guided missile engineering, New York, McGraw-Hill Book Co., Inc., 1959, viii + 497 pp. $10.

REMENIERAS, G., L'Hydrologie de l'ingenieur, Paris, Eyrolles, 1960, 413 pp. 40. NF.

SCHLICHTING, H., Boundary layer theory, 4th ed. (translated from the German by J. Kestin), New York, McGraw-Hill Book Co., Inc., 1960, xx + 647 pp. $16.50.

SHANLEY, F. R., Weight-strength analysis of aircraft structures, 2nd ed., New York, Dover Publications, Inc., 1960, xiii + 404 pp. $2.45. (Paperbound)

STANTAN, R. G., Numerical methods for science and engineering, Englewood Cliffs, N. J., Prentice-Hall, Inc., 1961, xii + 266 pp. $9. (classroom ed. $6.75)

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University of California, Berkeley, California
June 18 - 21, 1962

The U. S. National Congresses of Applied Mechanics are held every fourth year under the auspices of the U. S. National Committee on Theoretical and Applied Mechanics, a joint committee of the American Institute of Chemical Engineers, the American Mathematical Society, the American Physical Society, the American Society of Civil Engineers, the American Society of Mechanical Engineers, the Institute of the Aerospace Sciences, and the Society for Experimental Stress Analysis. These Congresses are planned to supplement the International Congresses of Applied Mechanics but not to compete with them. Accordingly, no effort is made to attract papers from outside the U. S. and Canada, although there is no rule against their presentation.

All research workers in the field are cordially invited to submit papers constituting original experimental or theoretical contributions to Applied Mechanics, including mechanics of rigid bodies and deformable solids, mechanics of fluids and gases, thermodynamics and heat transfer. Instructions to authors of papers are given at the end of this announcement. It is expected that papers accepted by the Editorial Commitee with the advice of recognized authorities, and presented at the Congress, will be published in full in the Proceedings of the Congress.

To be considered for presentation at the Congress, complete papers and manuscripts must be submitted to the Chairman of the Editorial Committee before January 1, 1962; to be scheduled for presentation the final manuscript of a paper must have been accepted before May 1, 1962. To avoid delays caused by overburdening reviewers and editorial staff, authors are urged to submit manuscripts well ahead of the deadline of January 1, 1962.

The papers will be grouped by subject and 30 minutes will be allotted for presentation and discussion of each paper. Arrangements will also be made for general lectures by outstanding authorities on subjects of general interest to members of the Congress. Facilities will be provided for informal discussion and social contact.

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Manuscripts should be in final form, as corrections in proof are extremely expensive; the cost of corrections in proof representing deviations from the manuscript or caused by insufficient identification of mathematical symbols in the manuscript will be charged to the authors. Authors are advised to retain carbon copies of their manuscripts as the original manuscripts will not be returned with the proofs.

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